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ABSTRACT

This program planning guide for a two-year postsecondary nuclear instrumentation and control technician program is designed for use with courses 33-35 of thirty-five in the Nuclear Technology Series. The purpose of the guide is to describe the nuclear power field and its job categories for specialists, technicians and operators: and to assist planners, administrators, faculty, and industrial and community educational advisors in establishing and conducting relevant training programs. The guide provides a model curriculum plan and suggests methods for adapting the modular materials to curricula tailored to specific localities or employer needs. Also included is information about educational facilities, equipment, staffing, and instructional materials needed for training technicians and operators in this field. Appended material includes the technical specialty courses and module titles and descriptions: suggested workforce needs survey instrument for nuclear instrumentation and control technicians: equipment list with cost, quantity, and vendor data: and suggested library references and materials. (A master index to the series and other suggested program planning guides are available--see CE 026 856 and CE 026 639-642.) (LRA)

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NUCLEAR TECHNOLOGY SERIES

NUCLEAR INSTRUMENTATION AND CONTROL TECHNICIAN

A SUGGESTED PROGRAM PLANNING GUIDE

(REVISED JUNE 80)

CE 026 643

AUG 1980

U S DEPARTMENT OF HEALTH, EDUCATION & WELFARE
NATIONAL INSTITUTE OF EDUCATION

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1977

The Nuclear Technology Series consists of five curricula (see page 2).

Nuclear Instrumentation and Control Technician.
Nuclear Reactor (Plant) Operator Trainee.
Radiation Protection Technician.
Nuclear Materials Processing Technician.
Nuclear Quality Assurance/Quality Control Technician.

The Nuclear Instrumentation and Control Technician curriculum consists of the following 12 technical specialty courses made up of 86 instructional modules (see Appendix B for module titles and descriptions):

Radiation Physics.
Radiation Protection I.
Principles of Process Instrumentation.
Heat Transfer and Fluid Flow.
Introduction to Nuclear Systems.
Instrumentation and Control of Reactors and Plant Systems.
Radiation Detection and Measurement.
Reactor Physics.
Introduction to Quality Assurance/Quality Control.
Control Systems I.
Control Systems II (Advanced).
Power Plant Electrical Systems and Components.

Availability: Instructional modules are available individually or by courses from:

Center for Occupational Research and Development
4800 Lakewood Drive
Waco, Texas 76710
Telephone (817) 772-8972

FOREWORD

In response to the needs of the nuclear power industry, a curriculum has been designed, and 86 instructional modules have been developed. These modules may be used by two-year post-secondary technical institutions to train men and women to work as nuclear instrumentation and control technicians. The instructional materials also are useful to employers for training or updating their employees in company-sponsored educational programs.

The purpose of this Guide is to describe the nuclear power field and its job categories for specialists, technicians and operators, and to assist planners, administrators, faculty and industrial and community educational advisors in establishing and conducting relevant training programs.

The Guide provides a model curriculum plan and suggests methods for adapting the modular materials to curricula tailored to specific localities or employer needs. Also included is information about educational facilities, equipment, staffing and instructional materials needed for training technicians in this field. This information is based on task inventories conducted by the Center for Occupational Research and Development staff and on the collective thinking of the National Steering Committee for Nuclear Technician Training, made up of employers, technical specialists and educators.

Funds for this project were provided under contract from the U.S. Office of Education, Bureau of Adult and Occupational Education, Mr. William M. Berndt, Project Officer. Additional assistance in the form of valuable advice, encouragement and guidance was provided by Dr. Walter J. Brooking, Project Monitor.

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The staff of the Center for Occupational Research and Development wishes specifically to acknowledge the valuable contributions made to this project by three groups. First, a special thanks goes to the two project advisors.

Dr. Maurice W. Roney, Texas State Technical Institute.
Mr. W. Scott Fellows, Director of Special Programs,
Southern States Energy Board.

Second, the invaluable assistance of a dedicated National Steering Committee for Nuclear Technician Training merits special acknowledgment: the members of this committee are listed in Appendix A.

Thirdly, the quality and relevance of this curricula and the instructional materials owe much to the technical resource personnel, writers, module reviewers, and editors too numerous to identify by name but who must be recognized in their entirety.

Staff members of the Center for Occupational Research and Development who have contributed significantly to this entire project and to the materials contained in this guide include:

Mr. Vernon Woolf, Associate Project Director.
Mr. Ellis Lindsey, Research Associate.
Ms. Kay Liston, Project Coordinator.

Daniel M. Hull
Project Director

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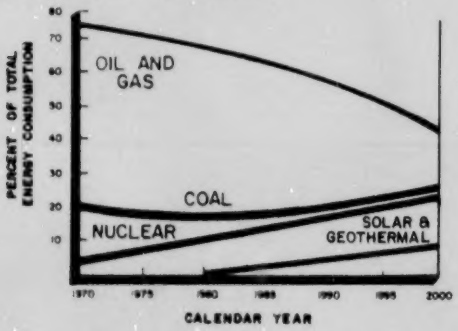
NUCLEAR TECHNOLOGY

Nuclear fission – atom splitting – generates heat, providing an energy source for electrical plants. Its world-wide impact is rapidly increasing. At the beginning of 1980, 67 on-line nuclear-fueled plants provided 13 percent of America's electrical power. By 2000, this percentage will have doubled. And outside the United States, nations on nearly every continent are looking to nuclear fission for electrical power generation.



Projected consumption of various energy sources.

Indeed, nuclear reactors have come of age in the electrical power generating industry. Genuine concerns, embodied in laws and regulations, have required nuclear technology to be among the safest and cleanest processes available for electrical power generation.

Today, nuclear technology, once recognized for only its destructive ability, has become a multipurpose field of endeavor, providing many human services and offering an array of new technical career opportunities.

CAREERS IN NUCLEAR TECHNOLOGY

As a technology, the nuclear field has passed the state of basic research through the phase of applied research and into an era of practical application. The first commercial nuclear electrical power plant (Shippingport, Pennsylvania) came on-line in 1958. But nuclear fission had already proved its capability as a virtually limitless and inexhaustible power source abord the submarine, USS Nautilus – this first nuclear powered vessel began its sea trials in 1955. Many of industry's early nuclear operators and technicians were former seamen from the Navy's extensive nuclear fleet.

The world's first nuclear-powered vessel, the USS Nautilus.

Today, a few technical-vocational schools offer limited nuclear programs. But industry's ability to absorb trained technicians with nuclear skills is barely affected by graduates of these programs. Ingress into industry from the Navy has dwindled to an ineffective trickle.

Recent workforce needs assessments, made and supported by a strong National Steering Committee (Appendix A) composed of employers of nuclear operators and technicians, identified a present (1977) need in industry for half a million people with nuclear skills and knowledge. Also, five major technical occupations in or directly related to electrical power plant/nuclear reactor operation were identified:

Nuclear Instrumentation and Control Technician.

Nuclear Reactor (Plant) Operator Trainee.

Radiation Protection Technician.

Nuclear Materials Processing Technician.

Quality Assurance/Quality Control Technician.

The major emphasis of this Guide is the preparation of Nuclear Instrumentation and Control Technicians. The educational material described herein offers nuclear-option curricula for individuals working with radioactive materials in each of the five technical occupations. Therefore, a general job description of each of these major technician classifications associated with power plants is included, along with a brief mention of other opportunities in nuclear technology.

NUCLEAR INSTRUMENTATION AND CONTROL TECHNICIAN

Instrumentation long has enjoyed its own "technology." A nuclear instrumentation technician must employ all the skills and knowledge attributable to the basic technology plus those

Key			
● Operable	72	Reactors with operating licenses	52,396 MWe
○ Under Construction	92	Reactors with construction permits	101,148 MWe
◘ Limited Work Authorizations	4	Reactors with limited work authorizations ..	4,112 MWe
▲ On Order	30	Reactors on order (including 4 units not sited on map)	35,082 MWe
	198	Total	192,738 MWe

Nuclear-fired electrical power plant distribution and nuclear materials handling plants. (Courtesy U.S. Atomic Forum.)

unique to nuclear. Duties include inspection, analysis, calibration, repairs and routine maintenance of instrumentation and control systems (including computer maintenance) throughout the plant.

Calibration, maintenance and repair of nuclear instruments require special training.

Upon employment, graduates will be taught many specific job-related tasks. Their intensive backgrounds in electronics and their knowledge of nuclear instrumentation and control systems should allow them to do well in this on-the-job training. After this preparation, they should become valuable assets to firms that employ them.

Instrumentation and control technicians are important links in nuclear processes; for example, nuclear plant operators depend heavily upon the skill of such technicians for the calibration and proper operation of vital instruments.

POWER PLANT OPERATOR TRAINEE

The nuclear reactor (plant) operator is responsible for proper routine and emergency operation of the facility. This job is the most critical in the plant from the standpoint of responsibility and licensing requirements. Training, experience and performance under stress all figure into the ultimate selection process by which such an operator is licensed by the

San Onofre nuclear power plant near San Clemente, California.

Nuclear Regulatory Commission (NRC) and employed by an electric utility. (It has been noted that any shutdown, due to accident or operator error, of an average 1000-MWe power plant can result in a minimum revenue loss equivalent to an operator's salary over a ten-year period. Thus, an operator must combine good judgment with exceptional skill — a combination of learned capabilities best founded on adequate technical education and experience.)

Other technical occupations described briefly in the following paragraphs are plagued with arrays of job titles but, for simplicity, each is limited to the most common formal title.

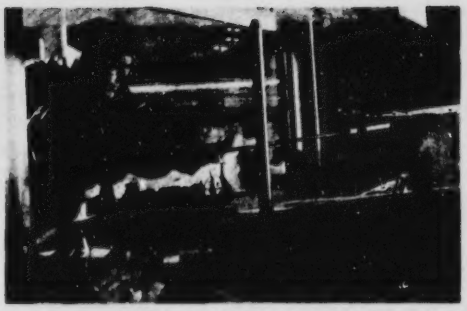
RADIATION PROTECTION TECHNICIAN

An inherent characteristic of energy is its potential for doing harm to life and property if allowed to get out of control. This potential existed with the most primitive uses of fire by man, and it exists in the most advanced applications of nuclear fission. Special care must be taken to prevent uncontrolled nuclear radiation. Skilled technicians must monitor and control radiation levels. Radiation protection technicians measure the intensity and identify types of radiation and contamination.

Radiation protection – protection for employees and the environment.

NUCLEAR MATERIALS PROCESSING TECHNICIAN

This technician performs a variety of tasks related to the milling, conversion, separation and fabrication of nuclear materials and fuels, and may perform tasks related to fuel reprocessing, waste management, radioactive materials and materials irradiation.



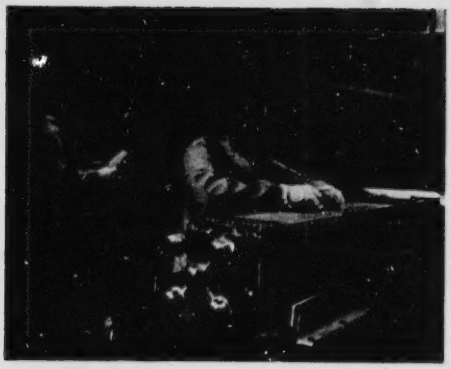
Materials handling requires skill and knowledge.

QUALITY ASSURANCE/QUALITY CONTROL TECHNICIAN

Quality assurance (QA) and quality control (QC) consists of testing, inspecting and auditing materials, equipment and processes to ensure that all are maintained within specified qualitative and quantitative limits.

The QA/QC technician may conduct nondestructive testing of materials or use other methods for inspecting materials and workmanship for compliance with regulations and specifications. Duties may include electrical, civil, mechanical and welding inspection of equipment, materials, processes and structures during construction, operation and maintenance of a power plant.

Trained QA/QC technicians ensure quality materials and workmanship.



Support industries, such as nuclear fuel rod fabrication, provide job opportunities.

OTHER OPPORTUNITIES IN NUCLEAR TECHNOLOGY

In general, job descriptions indicated above apply to the nuclear power plant workforce – the requirements for nuclear technicians are concentrated in this industry; however, equally challenging and rewarding opportunities exist in the vast support and peripheral industries that supply equipment and materials to the utility companies. Also, nuclear research and medicine utilize technicians in large numbers. Thus, applications of the technology, already widespread, continue to expand.

In general, expanding technological applications indicate an expanding workforce requirement. Certainly, this generality holds true for the nuclear field.

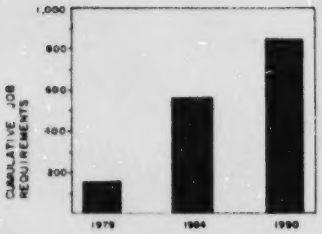
NATIONAL WORKFORCE REQUIREMENTS

Nuclear power plants span the nation and much of the developed world. And, because the nuclear technology workforce requirements and growth applicable to this Guide appear proportional to nuclear power production, the existence and foreseeable expansion of nuclear plants may be used as a needs assessment base.

In 1970, Wayne L. Rodgers, Director of Eastern Idaho Vocational School (Idaho Falls) correctly prophesied:

> The heaviest employment of nuclear technicians is with the Federal government. However, the distribution in employment is shifting toward reactor operators, fuel processors, and reactor vendors and manufacturers.

By 1990, a thousand Nuclear Instrumentation and Control Technicians will be required for the workforce, as indicated by the graph on the following page.



The principal employers of nuclear instrumentation and control technicians are as follows:

- Electric Utilities.
- Nuclear Instrumentation and Control Component Manufacturers.
- Nuclear Research Reactor Facilities.
- Nuclear Materials Handling and Processing Facilities.
- Nuclear Power Plant Contractors and Consultants.
- Other Electronic and Instrumentation Industries.

KNOWLEDGE AND SKILLS REQUIREMENTS FOR NUCLEAR INSTRUMENTATION AND CONTROL TECHNICIANS

A significant element of any needs assessment is a determination of the specific skills graduate technicians must possess to complete those tasks that they reasonably might be expected to perform. (Sometimes these requirements are referred to as "entry-level skills.") These determinations must identify the minimum knowledge and skills a student should acquire prior to graduation.

Nuclear instrumentation and control applications in a nuclear power plant usually can be divided into four types of systems: (1) neutron monitoring systems, (2) reactor protection systems, (3) process radiation monitoring system, and (4) area and environmental monitoring system. In addition to this is the instrumentation associated with the counting room and personnel radiation-protection monitoring.

A Nuclear Instrumentation and Control Technician is a specialist in the maintenance and repair of instrumentation and control systems used in a nuclear facility. The work demands a broad background in electronics, mechanics and mathematics and a specific knowledge of advanced instrumentation and control systems.

Men and women who are students of this technology study electronics, thermal and fluid systems, instrumentation, radiation protection, reactor systems, computer systems, mathematics and mechanics, and they acquire an extensive knowledge of nuclear instrumentation.

Many of the trainees currently recruited by industry for this technology have electronic and instrumentation backgrounds but lack training in radiation protection and nuclear instrumentation. When implemented, this curriculum should help fill the need for trainees prepared in these additional fields. Graduates should be very attractive to nuclear employers, and be in demand in many phases of the electronics industry.

Electronics technicians trained in digital and analog circuitry and systems, as well as in nuclear radiation, its detection and measurement, process control instrumentation, electro-pneumatic, electro-mechanical, and electro-hydraulic components and systems, are needed by every nuclear power plant.

The instrumentation and control technician must possess the knowledge and ability to perform the following tasks, whether employed in a nuclear power plant or in related areas.

- Make routine inspections of equipment and components.
- Calibrate equipment after repair; and calibrate new equipment and construct calibration charts.
- Perform routine and preventative maintenance on various types of equipment, including electronic and pneumatic.
- Make data reduction, and prepare reports.
- Perform error-analysis measurements.

- Assist in equipment performance monitoring.
- Maintain control systems.
- Assist in procedures, records, and schedules for systems maintenance, repairs, and calibrations on system devices.
- Assist in maintenance of computer system.
- Provide basic maintenance upkeep in computer instrumentation.
- Maintain a system of check procedures, and schedule routine inspections of computer systems.
- Repair and calibrate system devices.

Program requirements — faculty, facilities, equipment, supplies and cost estimates — (discussed in the following section) include classroom-laboratory-office-storage floor space, and a department head with appropriate technical comprehension and industrial experience. Also, such a program calls for a quality curriculum and appropriate instructional materials.

INSTRUCTIONAL PROGRAM

The curriculum described in this section was derived from the task inventory described in the first section.

CURRICULUM

The Nuclear Instrumentation and Control Technician curriculum incorporates learning objectives and supporting objectives based upon related knowledge, as well as upon the tasks that the technician is expected to perform in industry today.

Although the curriculum design specifically relates to training nuclear instrumentation and control technicians for power plants, every course and every module invites multiple application, as demonstrated in the chart on page 12.

An example of the curriculum is indicated below.

NUCLEAR INSTRUMENTATION AND CONTROL TECHNICIAN PROGRAM

	Periods Per Week		
	Lec	Lab	Total
First Quarter			
Introduction to Nuclear Technology	2	3	5
*Radiation Physics (Course 1)	3	3	6
Mathematics I	3	2	5
Fundamentals of Electricity & Electronics	3	3	6
Technical Physics I	3	3	6
	14	14	28
Second Quarter			
*Radiation Detection & Measurement (Course 11)	3	4	7
Technical Physics II	3	3	6
*Radiation Protection I (Course 2)	3	3	6
Mathematics II	2	3	5
Electronic Devices I	3	4	7
	14	17	31
Third Quarter			
Microcomputers	3	3	6
*Introduction to Quality Assurance/Quality Control (Course 14)	2	3	5
Blueprint Reading	1	3	4
*Principles of Process Instrumentation (Course 3)	3	3	6
Electronic Devices II	3	4	7
	12	16	28
Fourth Quarter			
*Power Plant – Thermal (Course 4, Modified only for I&C)	2	3	5
*Introduction to Nuclear Systems (Course 5)	3	4	7
Measurements & Calibrations	2	3	5
*Reactor Physics (Course 12)	3	4	7
Digital Electronics	3	4	7
	13	18	31
Fifth Quarter			
Electro-Mechanical Controls	3	3	6
Linear Integrated Circuits	3	3	6
*Instrumentation & Control of Reactors & Plant Systems (Course 6)	2	3	5
Computer Systems I	2	3	5
*Control Systems I	3	3	6
	13	15	28
Sixth Quarter			
Introduction to Technical Communications	2	2	4
*Control Systems II	3	4	7
Computer Systems II	2	3	5
*Power Plant Electrical Systems & Components (Course 10)	4	8	12
	11	17	28

*Technical speciality courses for which instructional modules have been developed.

COURSE DESCRIPTIONS

Each course in the curriculum is described to indicate both its content and its relevance to the overall program.

FIRST QUARTER

Introduction to Nuclear Technology.
An introduction to the principles and applications of nuclear energy. Student is introduced to basic principles involved in nuclear radiation, nuclear sources, reactors and fuel cycles. Essential features of a nuclear power plant are discussed. Student also learns how radionuclides and radiation have application in industry and medicine. Nuclear safety will be emphasized and radiation effects evaluated. Lab sessions will include field trips, films and guest speakers. (Note: Materials for this course should be obtained from nuclear utility public relations offices.)

*Radiation Physics.
An introductory course in basic concepts of nuclear radiation. Main topics covered include atomic and nuclear structure, radioactivity and interaction of radiation with matter. Student is introduced to basic radiation and measuring instruments, including Geiger-Müeller counters and personnel monitoring devices.

Mathematics I.
A course in algebra, geometry and introductory trigonometry. Includes ratios, linear equations, plotting, reading and interpreting graphs and sinusoids. Math labs are problem sessions, preferably conducted by the nuclear faculty.

Fundamentals of Electricity and Electronics.
A study of basic principles of direct current and alternating current, series and parallel circuit analyses utilizing Ohm's and Watt's laws, basic motors, generators and relays.

Technical Physics I.
An introduction to the principles and applications of the concepts of force, work, rate and resistance. Specific topics in each of these concepts will be discussed with special attention to applications of physical concepts in nuclear power plants. Some specific topics included are: electric and magnetic forces and fields, heat energy, velocity and displacement, flow measurement, fluid resistance and heat flow.

*Technical specialty courses.

SECOND QUARTER

*Radiation Detection and Measurement.
A course in principles and methods used to detect and measure radiation, with emphasis on ionization and scintillation detectors. Statistics of counting will be introduced. Properties of α, β and γ will be studied.

Technical Physics II.
An introduction to the principles and applications of power potential and kinetic energy, force transformers, energy convertors and transducers. Nuclear-power-plant relevant applications are emphasized. Hydraulic power, heat exchangers, pitot tubes, turbines, fluid pumps, electric motors, Bourdon tubes and temperature measuring devices are among the applications used to illustrate physical principles.

*Radiation Protection I.
An introductory course to familiarize student with the field of radiation protection, the art and science of protecting human beings from injury by radiation. Specific topics include dose and exposure measurements and units, biological effects of radiation, Federal Regulations of exposures and internal exposure evaluations.

Mathematics II.
A continuation of Mathematics I; algebra includes logarithms to base 10 and base e and exponentials; geometry and trigonometry emphasizing slopes, rates of change and solutions of equations and problems with transcendental functions.

Electronic Devices I.
A study of semiconductor and vacuum tube fundamentals. Mathematical analysis of static characteristics, dynamic characteristics, bias techniques and thermal considerations will be covered.

THIRD QUARTER

Microcomputers.
A course covering general concepts such as computer codes and major parts of most computers, operations and programming with elements of BASIC programming. Specific techniques for introducing and releasing both digital and analog data to microcomputers are reviewed. Data communication ideas and microcomputer troubleshooting techniques are covered.

*Introduction to Quality Assurance and Quality Control.
An introductory course in quality assurance and quality control, including such topics as history and purpose of quality control, terms and definitions, codes and standards, publications and quality assurance/quality control procedures.

Blueprint Reading.
A basic study of industrial blueprints, process flow sheets, piping and instrumentation symbols, schematics, logic diagrams and computer circuitry.

*Principles of Process Instrumentation.
A course to teach principles of operation, calibration and maintenance of process instrumentation found in electrical power generating plants (includes all non-nuclear instrumentation). Specific topics include flow, temperature and pressure instrumentation.

Electronic Devices II.
Analysis of static and dynamic characteristics, frequency effects on amplifiers, large signal amplifiers and d.c. coupled amplifiers. Special purpose devices will be covered with emphasis on digital integrated circuits and their applications.

FOURTH QUARTER

*Power Plant – Thermal.
A study of power plant fundamentals, thermal cycles and the principles of fluid flow and heat transfer processes in nuclear reactor systems.

*Introduction to Nuclear Systems.
This course will include a basic understanding of all major components of the reactor core, pressure vessel, shields, and primary cooling water systems. Differences between PWR's and BWR's will be discussed. The basic nuclear fuel cycle also will be discussed.

Measurement and Calibration.
A study of electronic test instruments, proper use of instruments, accuracy and limitation of measurement and calibration techniques.

*Reactor Physics.
A basic course in the principles of nuclear reactor operation, including fission process, neutron balance, neutron slowdown, criticality and reactor kinetics. Actual characteristics of an operating nuclear power reactor are discussed. (It is highly desirable to use a nuclear reactor or simulator in this course, both as a neutron source in conducting experiments and as a means of gaining hands-on experience.)

Digital Electronics.
A continuation of Electronic Devices II. The further study of digital circuits with emphasis on integrated circuits and their input/output relationships. Troubleshooting techniques will be discussed.

*Technical specialty courses.

FIFTH QUARTER

Electro-Mechanical Controls.
A study of switches, relays, mechanical counter, mechanical motor control and alarm circuits.

Linear Integrated Circuits.
A study of operational amplifier characteristics, operations, stabilization, testing and feedback techniques for application of operational amplifiers in computation, measurements, instrumentations and active filtering.

*Instrumentation and Control of Reactors and Plant Systems.
A study of nuclear reactor instrumentation systems, nuclear plant controls, control element drive mechanisms, design and operation characteristics of electrical control systems, turbine generation interfaces, and electrical distribution and reactor regulating systems.

Computer Systems I.
An introduction to digital computers used for process control and data handling.

*Control Systems I.
Includes an introduction to block diagrams, review of operational amplifiers, transfer function, input/output devices, pneumatic control mechanisms and control valves.

SIXTH QUARTER

Introduction to Technical Communications.
An introduction to the nature of communication skills and thinking processes, with practical exercises in writing, reading, speaking, spelling and vocabulary as related to technical areas. Emphasis on writing and making reports, utilizing the use of a memoranda.

*Control Systems II.
Includes an introduction to control system theory, transient response, control units, frequency response analysis, operational checks and adjustments, and microprocessor utilization and programming.

Computer Systems II.
A continuation of Computer Systems I, with emphasis on basic upkeep, maintenance, and calibration of process control and data handling computers.

*Power Plant Electrical Systems and Components.
Includes electrical distribution in a typical power plant, instrumentation and control for major plant components, an introduction to display devices, instrument recording devices, process control devices, cathode ray tube systems, preventive maintenance for systems and components and instrument reliability.

COURSE OPTIONS

As noted previously, almost any nuclear-related training program could utilize material from the model curriculum. Nuclear technology options for these technicians are illustrated in the chart below. Courses 1, 2, 11 and 14 are common to each of the five technology curricula. Numerous other courses are common to two or more of the curricula.

At least two program options or specialties are recommended at schools for several reasons. 1) Instrumentation and control job requirements exclude some students for reasons other than educational non-achievement; i.e., personality traits. 2) A temporary shift in workforce requirements may favor an option. 3) Student interest may change after the first year of co-op experience.

COURSE NO.	TECHNICAL COURSE TITLE	NUMBER OF MODULES	NUCLEAR REACTOR (PLANT) OPERATOR TRAINEE	RADIATION PROTECTION TECHNICIAN	NUCLEAR MATERIALS PROCESSING TECHNICIAN	NUCLEAR QUALITY – ASSURANCE/QUALITY – CONTROL TECHNICIAN	NUCLEAR INSTRUMENTATION AND CONTROL TECHNICIAN
1	Radiation Physics	6	1	1	1	1	1
2	Radiation Protection I	6	2	2	2	2	2
3	Principles of Process Instrumentation	6	3		3	3	3
4	Heat Transfer and Fluid Flow	9*	3				4
5	Introduction to Nuclear Systems	6	4	3		4	4
6	Instrumentation and Control of Reactors and Plant Systems	6	5				5
7	Reactor Operations	7	6				
8	Reactor Safety	5	5				
9	Reactor Auxiliary Systems	4	6				
10	Power Plant Systems	9	5				
11	Radiation Detection and Measurement	6	2	2	2	2	2
12	Reactor Physics	8	4				4
13	Power Plant Chemistry	7	5	4			
14	Introduction to Quality Assurance/ Quality Control	9	3	3	3	3	3
15	Metallurgy and Metals Properties	9	3		4	3	
16	Mechanical Component Characteristics and Specifications	8	4			4	
17	Radiation Protection II	5		4	4		
18	Radiological Emergencies	7		4			
19	Radiation Shielding	6		5			
20	Radiation Monitoring Techniques	7		5	5		
21	Radioactive Materials Disposal and Management	7		6			
22	Advanced Radionuclide Analysis	7		6			
23	Nuclear Chemical Processes	7			6		
24	Nuclear Systems and Safety	6**			6		
25	Radioactive Material Handling Techniques	8***			8		
26	Nondestructive Examination (NDE) Techniques I	7				4	
27	Metrology	8			3	3	
28	Welding Inspection	11				5	
29	Civil/Structural Inspection	8				6	
30	Mechanical Inspection	9				5	
31	Quality Assurance Practices	8				6	
32	Nondestructive Examination (NDE) Techniques II	6				6	
33	Control Systems I	6					5
34	Control Systems II	7					6
35	Power Plant Electrical Systems and Components	7					6

*Course 4 modified for I&C only

**Module 24-1 is 12-1
24-2 is 12-2
24-3 is 12-3

***Module 25-6 is 21-1
25-7 is 21-6
25-8 is 21-4

NOTE: Numbers in columns denote suggested quarter for use of the courses.

INSTRUCTIONAL MATERIALS

The basis of a sound instructional program is well prepared materials. If scrupulously reviewed by educators and employers, revised and tested, such materials best serve the instructional program, the students and the ultimate employers. The best materials also meet stringent content requirements for flexibility, relevance, currency and validity.

MATERIAL CONTENT AND FORMAT

As noted earlier, nuclear technology encompasses a variety of technical job opportunities with equally great variations in knowledge-and-skills requirements. A curriculum that offers a two-year instrumentation and control technician program with options for several nuclear-related jobs must be flexible enough to be adapted to specific employer needs on a local basis. Modular materials allow pin point selection of appropriate instructional units; for example, the instrumentation technician, whose major involvement is with instruments, with only an incidental involvement in nuclear, should be allowed to select those instructional units applicable to that limited involvement. The flexibility of brief, single-subject, self-contained modules allows a curriculum – whether a seminar, short course, course option or full course – to be custom designed to meet specific needs.

The curriculum material is passed through a variety of critical reviews to ensure its relevancy. Local instructional needs, determined by a local or regional needs assessment and task inventory, makes selection of material relevant to local, current needs possible.

Historically, technical instructional materials have evolved slowly. Too often, materials became available at about the same time they became obsolete. To eliminate this problem, the materials described in this Guide are being offered within months – sometimes, weeks – following their intial preparation by authors and reviewers involved in the state-of-the-art technology. Further, through continuing efforts of the National Steering Committee for Nuclear Technician Training, technological advances as well as national employment opportunities are reviewed, and relevant data is passed on to institutions and organizations using the materials.

The materials are updated as necessary to ensure currency. The most effective manner of ensuring currency, however, is for users of the material to utilize their local industrial advisory committee (IAC) to keep the local program up to the minute on technological changes, variations and workforce requirement fluctuations. (Note: An IAC is described in the following section in detail.)

From the educator's standpoint, educational materials must assume a valid educational format. In this case, the materials are presented in a strictly cognitive form; that is, objectives are stated in "action" terms (perform, calibrate, draw, list, measure); and each module as well as its procedures emphasizes manipulative skills, founded on valid, relevant theory and practice.

Thus, each module, as well as the entire curriculum for nuclear instrumentation and control technicians, consists of valid, current, relevant and flexible materials.

MODULE ELEMENTS

Instructional modules developed specifically for this nuclear instrumentation and control technician curriculum contain these basic elements:

Introduction: Identifies topic (and often includes rationale for studying the material).

Module Prerequisites: Identifies knowledge and skills students should possess before studying the module.

Objectives: Clearly identifies what the student is expected to know and do upon completion of module. Objectives are stated in terms of action-oriented behaviors, including such terms as "operate," "measure," "calculate," "identify" and "define," instead of words with many interpretations, such as "know," "understand," "learn" and "appreciate."

Subject Matter: Presents background, theory and techniques supporting the objectives. (Subject matter is written with the technical student in mind.)

Exercises: Provides practical problems to which student can apply new knowledge from module study.

Materials: Identifies equipment required to complete laboratory exercises.

Procedures: Presents experiments or "hands-on" activities, including step-by-step instructions. (Experiments are designed to reinforce student learning.)

Data Tables: Included in most first-year or basic-course modules, the data tables help students learn how to collect and organize data.

Reference Materials: Presents suggestions for supplementary reading.

Test: Measures each student's achievement against objectives stated at the beginning of the module.

Modules average approximately 30 typewritten pages, including illustrations. (Illustrations normally are line drawings that are easily understood and can be reproduced on copy machines for overhead projection.) New modules can be added easily, or existing ones modified, for self-paced instruction or short courses.

A description of the courses and their modules appears in Appendix B. Course and module titles of materials developed for the other four curricula are indicated also.

An exhaustive index for each course is scheduled for completion in August, 1980. In addition to this index in the back of each course, a general index to all 35 courses will be available in a separate volume. These indexes will be excellent aids (1) for planners who wish to determine the exact content of each module or course, (2) for students and instructors who must locate materials in the various courses, and (3) for researchers who use the courses as library or plant references.

INDUSTRY TRAINING PROGRAMS

Planning a training program within an industry differs from institutional planning — employer needs dictate program content. The following examples (Duke Power Company and General Electric) of industrial preparation programs for nuclear instrumentation and control technicians show two approaches, both of which have proved to be effective.

DUKE POWER COMPANY INSTRUMENTATION AND CONTROL CURRICULUM (14 Weeks or 534 Class Hours)	
Class Hours	Parallel CORD Course Number
1st Week (40 Hours)	
2 Orientation	1, 2, 3, 5, 6, 33, 34, 35
1 Safety Procedures	
1 Electrical Hazards and Safe Practices	
1 Safety in Hazardous Areas	
1 Electrical Safety Equipment	
2 First Aid	
2 Batteries and d.c. Fundamentals	
2 Magnetic Fields	
2 Basic Circuits and Laws	
4 a.c. Fundamentals	
4 Inductance and Capacitance	
4 Resistive, Inductive and Capacitive Circuits (RLC)	
2 Print Reading Review	
3 Control Circuits	
4 Circuit Breaker Wiring	
3 Building Feeder Circuits	
2 d.c. Distribution Systems	
2nd Week (40 Hours)	
2 d.c. Distribution System (Total 4 hours)	3, 33, 34, 35
4 Rod and Reactor Control System	
4 Pressurizer Control Circuitry	
1 Troubleshooting by Circuit Analysis	
2 Solid State	
2 Diodes and Semiconductors	
2 Transistor Principles	
2 Transistor Amplifier Configurations	
2 Thyristers	
2 Zener Diodes	
1 Tunnel Diodes	
1 Silicon Control Rectifiers	
2 Operational Amplifiers	
2 Insulated Gate FET	
8 Number Systems	
3 Logic Functions and Boolean Equations	
3rd Week (22 Hours)	
5 Logic Functions and Boolean Equations (Total 8 hours)	33, 34, 35
7 Logic Flip-flops and Registers	
7 Storage Devices	
3 Conversion Circuits	
4th Week (32 Hours)	
5 Conversion Circuits (Total 8 hours)	1, 3, 5, 6, 33, 34, 35
8 Nuclear Theory	
5 Detector Theory	
8 Nuclear Instrumentation	
4 Control Rod Drives	
2 Pressurizer Level Control	
5th Week (40 hours)	
6 Pressurizer Level Control (contd.) (Total 8 hours)	3, 5, 6, 33, 34, 35
8 Pressurizer Pressure Control	
8 Steam Generator Level Control	
8 Feedwater Control	
8 Reactor Protective System	
2 Engineered Safeguards	

Class Hours		Parallel CORD Course Numbers
	6th Week (40 Hours)	
4	Engineered Safeguards (contd) (Total 6 hours)	3, 4, 6, 33, 34, 35
3	Incore Instrumentation	
4	Reactor Control Systems	
2	T-Ave Control	
4	Solid State Devices	
8	Diodes and Semiconductors	
8	Transistor Principles	
7	Transistor Amplifier Configurations	
	7th Week (40 Hours)	
5	Transistor Amplifier Configurations (contd) (Total 12 hours)	33, 34, 35
6	Thyristers	
6	Zener Diodes	
6	Tunnel Diodes	
8	Operational Amplifiers	
4	Insulated Gate FET	
5	Logic Functions and Boolean Equations	
	8th Week (40 hours)	
3	Logic Functions and Boolean Equations (contd) (Total 8 hours)	33, 34, 35
8	Logic Flip-flops and Registers	
8	Storage Devices	
16	Conversion Circuits	
1	Construction of Meters	
1	Principles of Test Equipment	
2	Switchboard Metering	
1	Energy Measurements	
	9th Week (40 hours)	
3	Ohmmeters and Meggers	6, 33, 34, 35
1	Wheatstone Bridge	
4	Indicating and Recording Instruments	
1	Power Supplies	
4	Oscilloscopes	
4	Maintenance, Repair, Test and Calibrate	
11	Transformers	
3	NEC Introduction	
3	Identification of Conductors and Associated Hardware	
6	Soldering and Printed Circuit Repairs	
	10th Week (40 Hours)	
10	Soldering and Printed Circuit Repairs (contd) (Total 16 hours)	33, 34, 35
24	Splicing, Terminal Connecting, etc., Kit Construction	
2	Principles of Motors and Generators	
2	Miscellaneous d.c. Equipment	
2	a.c. Alternators	
	11th week (40 hours)	
1	Single Phase Motors	35
4	Single Phase Motor Leads and Connections	
1	Synchronous Motors	
2	Polyphase Motors	
4	Polyphase Motor Connections	
6	Troubleshooting and Repair	
1	Motor Starting and Control Equipment	
1	Polyphase Motor Control	
8	Pushbutton Control Stations	
2	Circuit Breakers	
2	Fuses and Protective Devices	
2	Hi and Lo Voltage Circuit Breakers	
2	Metal Clad Switchgear	
4	Plant Demonstration Visit	

Class Hours		Parallel CORD Course Number
	12th Week (40 Hours)	
8	Troubleshooting and Repair of Circuit Breakers	34, 35
24	Wiring in Conduits and Enclosures	
1	Logical Approach to Equipment Problems	
1	Proper Use of Schematics and Drawings	
1	Standard Procedures for Troubleshooting Control Circuits	
5	Maintenance and Troubleshooting	
	13th Week (40 Hours)	
3	Maintenance and Troubleshooting (Total 8 hours)	33, 34, 35
1	Final Inspection Clearance, Release	
36	Instrumentation and Control Theory	
	14th Week (40 Hours)	
32	Instrumentation and Control Theory (Total 68 hours)	33, 34, 35
4	Inventory Tools	
4	Clean Up	

GENERAL ELECTRIC BWR INSTRUMENTATION AND CONTROL TRAINING PROGRAMS

	Courses	Weeks	Parallel CORD Course Number
1.	Nuclear Instrumentation	5	
	Lectures.	2	1,6
	Introduction.		
	Basic nucleonics.		
	Core and sensor layouts.		
	Neutron monitor system outline.		
	In-core neutron sensors.		
	Neutron sources.		
	Startup range monitoring.		33, 34, 35
	Source and intermediate range detector drives and controls.		
	Preamplifiers and control room monitors.		
	Power range monitoring.		33, 34, 35
	Local power range monitor.		
	Average power range monitor.		
	Flow units.		
	Rod block monitors or LPRM multiplexer.		
	Digital rod selection interface.		
	Traversing in-core probe (TIP).		
	Drive mechanism.		
	Indexer.		
	Drive control unit, disposal cask and valve module.		
	Process radiation monitoring.		11, 12
	System outline.		
	Main steam line monitors.		
	Pre- and post-treatment off-gas monitors.		
	Off-gas vent monitors.		
	Ventilation monitors.		
	Process water monitors.		
	Fission product/containment atmosphere monitors.		
	Reactor protection system.		12, 34, 35
	Philosophy.		
	Process sensors.		
	Logic diagrams.		
	Noise and installation problems and their solutions.		

Courses	Weeks	Parallel CORD Course Number
Laboratory. Source range monitor and pulse preamplifier. Intermediate range monitor and voltage preamplifier. Local and average power range monitors and power supplies. Rod block monitor and digital selection components. LPRM multiplexer. Area radiation monitor, logarithmic radiation monitor, solid state log rad monitor. Logarithmic count rate meter, TIP drive control unit.	3	35
2. On-site Nuclear Instrumentation (Taught at customer's BWR site)	Varies	
Introduction. Basic nucleonics. Core sensor layout. Neutron monitoring system outline. Operational amplifier review. Transistor and digital review. Startup range monitoring system. Source range monitor. Pulse preamplifier. Intermediate range monitor. Voltage preamplifier. Detector drain. Power range monitoring system. Local power range monitor. Average power range monitor. Flow unit. Rod block monitor. TIP system. Process radiation monitoring system. Area radiation monitoring system. Reactor protection system.		1, 6, 33, 34, 35
Optional Rod drive control system. Rod position information system. Rod worth minimizer. Rod sequence control.		
3. Reactor Manual Control System	5	
Introduction to RDCS. Redundant word philosophy. Transponder description and circuit analysis. Transponder test fixture description. Rod select module introduction. Circuit analysis of transmitter card. Data driver card. Activity section introduction. Circuit analysis of activity control card. Rod motion timer card. Input isolator card. Analyzer section introduction. Circuit analysis of analyzer card. Fault map card. Output isolator cards. Rod and detector display introduction. Display memory module introduction. Circuit analysis of source selector card. Rod data receiver card. Display clock card. DC buffer card.		33, 34, 35, 6

Courses	Weeks	Parallel CORD Course Number
File monitor card. Rod data memory card. Four-rod display discussion. RWM discussion. Rod sequence control system introduction. Circuit analysis of all buffer converter cards. Memory and clock/logic cards. Bypass control and switch cards. RPIS introduction. Position indicator probe description. Circuit analysis of probe multiplexer card. File control card. Ident generator card. Probe data receiver and processer cards. Drift and computer memory cards. Scan control card. Sampling card. RMCS review. Prerequisites: At least two years in digital electronics at the junior college level or equivalent.		
4. Process Instrumentation and Control Introduction. Process control loop introduction. Operational amplifier theory. Fundamentals of automatic process control. Automatic process control lab. Instruction on all Bailey signal conditioners. Temperature theory. Temperature devices. Pressure theory. Pressure switches. Flow theory. Level theory. Bailey pressure transmitters and differential pressure transmitters. Rosemount calibration trip system. Rosemount pressure transmitters and differential pressure transmitters. Level indicating devices – Fisher E/P transducers. Conductivity theory. pH theory. Turbidity theory. Instrument linkages. Barton differential pressure indicating switches. Barton transmitters – jet pump instrumentation system. Feedwater control system. RCIC system. Cleanup leak detection. Course wrapup.	4	3, 6, 11, 33, 34, 35
5. Rod Control and Information System Orientation. Plant coordinate system. Word format considerations and limitations. Rod control and information system introduction. Demonstration of time multiplexed data. Transponder card introduction and circuit analysis. Card circuit analysis. Branch amplifier. High-speed input and output.	7	3, 6, 11, 33, 34, 35

Courses	Weeks	Parallel CORD Course Number
Logic buffer. 5V logic input and output isolators. Floating low-level output isolator. File control. Probe multiplexer. Probe data receiver and processor. Drift memory. Bypass controller and switch. Request memory and routing. Activity word register and clock. Test word sync. Monitor and a.c. driver. Rod motion timer. Vector receiver and routing. Rod receiver, memory and compare. Condition generator. Command sync. Activity compare and display. Status memory and receiver. Beam control, driver, sensor and receiver. Transmitter, sequencer, demultiplexer and transform. Memory and sweep. Column and segment driver. Incore compare and transform. Activity driver and demultiplexer. Timing diagram application. Transponder test fixture introduction. Transponder troubleshooting. Rod action control system introduction. Rod pattern controller discussion. Rod interface system introduction. Prerequisites: Student should have at least two years of digital electronics training.		
6. Short courses include the following: Recirculation Flow Control (3 weeks) and Nuclear Instrumentation Refresher (10 days to 3 weeks).		

Modular curriculum materials adapt readily to such industrial training programs. Also, they fill the need for less comprehensive short courses and seminars presented by industry or technical association and intended for updating or upgrading employees.

Module procedures are directed primarily toward students at two-year institutions who have no experience or familiarity with specialized equipment. When an employer uses the instructional modules for employee retraining, the procedures or lab activities should be selectively omitted or replaced.

COOPERATIVE EDUCATION

This technology is adaptable to a cooperative arrangement: a plan which offers important advantages to students, to the school, and to employers of technicians. A cooperative education program provides an opportunity for a student to learn through coordinated study and employment experience. Students alternate periods of attendance at the institution where they study their technical program with periods of supervised employment in business or industry, which provides both training and work experience. The employment constitutes an essential element in their education. The students' employment should be closely related to the field of study in which they are engaged.

When students test their knowledge of theory in a work situation, study becomes more meaningful. Co-op students learn not only the essentials of the technology but also the importance of reliability, cooperation, and judgment as an employed worker in a chosen occupational field.

Co-op students' career choices are stimulated and strengthened by work experiences. A satisfactory work experience provided in a co-op program assists in stimulating the students' interest and effectiveness in the institutional phase of the program, making it more meaningful. The experience in a co-op program also assists students in knowing if they have made the proper occupational choice prior to completing their educational program and entering employment.

A class of students in cooperative technical programs usually spends the first semester or the first two quarters in school; then time is divided so that half the students have a semester or quarter of employment experience while the other half continues to study. During the next semester or quarter, the half who have worked return to their formal studies at school while the other half are employed. They usually alternate again so that each student has two semesters or at least two quarters of work experience in the program. The students' technical program is lengthened beyond the curriculum outlined in this Guide by an amount of time equal to the total length of the employment experience.

Specific employment is obtained, as circumstances permit, by the educational institution with the cooperation of the student. The institution regards the work-experience program as an integral part of the technician program as a whole. It is not regarded primarily as an opportunity for earning, although each student while working is paid at the prevailing wage scale for the job performed. Work reports by both the student and the employer are submitted to the school work program coordinator.

The cooperative work-experience program is an opportunity for the students to gain directly related experience, which makes them more valuable as employees. As a result of the work experience in particular establishments, many students are offered permanent positions upon completion of schooling. Cooperating establishments agree, however, not to make offers of employment that become effective before a trainee completes the program.

Cooperative programs provide opportunities for the educational institution to maintain close contact with employers in their various programs. This contact becomes a two-way channel of communication, which helps the educational institution keep its knowledge of specific employer needs in each technical field up to date. At the same time, it keeps employers acquainted with and involved in the institution's program(s).

PLANNING A PROGRAM

Planning should begin with establishment of an advisory committee and a determination of needs, followed by an evaluation of local potential for meeting such needs.* Considerations include:

Faculty.
Student Selection and Services.
Facilities.
Equipment.
Library.
Cost.

The extent and implications of each of these considerations are explored following the discussion of needs.

NEEDS DETERMINATION AND EVALUATION

By using accumulated data and a local industrial advisory committee, a program planner may develop a preliminary local or regional needs determination. The needs determination should consist of a survey documenting: number of existing employers; number of job vacancies; number of expected vacancies in 2, 5, and 10 years; other titles given this same job; job entry specifications; type of need – whether for new employees or retraining of existing employees; and anticipated salary range. A typical survey document is shown in Appendix C.

Once a program-sustaining need is determined, the planning considerations listed earlier should be given detailed attention.

ADVISORY COMMITTEE

The success of this program depends, to a great extent, on the formal and informal support of an advisory committee. This committee should be appointed by the chief administrative officer of the institution and should be comprised of local (or regional) employers of reactor operators and technicians. These members serve without compensation. The committee normally consists of about ten members who should serve from two to three years with staggered terms.

The local advisory committee should assist in studies to determine and define the following: the need for the technical assistant program; the knowledge and skills technicians will require; employment opportunities; available student enrollment; curriculum content; faculty qualifications; laboratory facilities and equipment; resources both within and outside the institution; and cost and financing of the program. If the survey indicates that a program should be initiated, and will be supported, the committee's help in planning and implementing it is invaluable.

The survey should take a form other than an informal question or two to associates of the committee members. It is suggested that a needs assessment instrument (similar to the one shown in Appendix C) be distributed to the employers in the region around the training institution. The form does not have to be elaborate and could be derived from performance objectives stated in this Guide. A checklist of performance objectives, filled out by various employers, gives the school a rather clear outline of the knowledge and skills needed by a trainee to be hired in the community.

When the survey instruments are returned to the school, they should be compiled, for use in a task inventory for the occupation. A review of the task inventory by the advisory committee is essential at this point. Resurveying at periodic intervals and changing course content accordingly keeps the training program up-to-date and ensures that trainees have a better chance for employment. In today's world

*In addition to the "ideas" presented in this Guide to facilitate curriculum planning, members of the project staff and the National Steering Committee are available for consultation and assistance in planning (and implementing) a nuclear program.

of specialized skills and employment, the old concept of curriculum by guess or by past procedures is a disservice to the student and to the training institution.

The advisory committee should understand that the program is not intended to make individual students proficient in all duties they might be asked to perform at all types of nuclear reactors. Proficiency in highly specialized work comes from experience and further education, or both. It is impossible to accurately predict the rate of change within various work situations. Employers should expect to provide reasonable on-the-job orientation to acquaint the new employee with operational procedures of the facility.

Upon implementation, the committee provides continuing liaison between the institution and employers. Frequently, the committee helps administrators obtain local funds and state and Federal support for the program. The committee also aids in placement of graduates of the program and in evaluating the performance of the graduates on the job. Such evaluations often indicate minor modifications that more closely align the program with employment requirements and opportunities.

The committee should meet as regularly as needed and should keep formal minutes of its proceedings (which could become, in compilation, an annual report of the proceedings). For further elaboration of the role and responsibilities of the advisory committee in technical education programs, refer to Riendeau's Advisory Committees for Occupational Education: A Guide to Organization and Operation.*

This Guide, designed primarily for planning and development of full-time programs in post high school institutions, can be used by the administrator of the institution and an advisory committee as a starting point for development of their own program. It can and should be modified where necessary and adapted to meet local needs and institutional criteria.

FACULTY

The effectiveness of the program and the curriculum depends largely upon the competence and enthusiasm of the teaching staff. With a qualified and interested faculty, a needed educational program may flourish. Qualified faculty members may exist at the institution or within the industry or organization planning the program, or it may be necessary to recruit a faculty from outside sources. In any event, faculty consideration includes these recommended items:

Numerical Requirements. The number of faculty members needed is based on the duties assigned each member, number of students in the program (first and/or second year) and number of courses scheduled for instruction. The typical teaching load is 18 – 24 class/lab hours per week with the department head assigned not more than 12 hours, allowing time for administrative duties. In the first year, the department head would be responsible for instruction of 24 students. A full-

*Albert J. Riendeau. Advisory Committees for Occupational Education: A Guide to Organization and Operation. New York: McGraw-Hill, 1977.

time instructor would be added in the second year. (See Appendix G for sample costing calculations.)

Competency. The department head should have a strong academic grounding in nuclear technology (BS degree in electrical engineering or equivalent) and suitable experience in industry (e.g., 2 years or more as operator trainee or technician). An instructor must have sufficient grounding in the technology (such as might be received from a well-organized tech school course), or work experience.

Availability. Qualified personnel must be available within a suitable time frame. (Assistance in identifying faculty requirements and in locating qualified personnel may be obtained from the local industrial advisory committee.)

Affordability. The salary structure is a prime consideration. Instructors with experience in the nuclear industry command salaries competitive with industry. An institution must be prepared to pay more for nuclear technology instructors than for welding or mechanic instructors – perhaps even more than some of the deans or campus managers.

Technical programs are designed to produce supportive employees who increase the effectiveness of the total workforce. This principle should be applied to increase the effectiveness of the teaching staff.

Adequate time should be set aside to allow new staff personnel to review the curriculum materials, to visit – if possible – a successful program and its faculty, and to engage in a brief teacher training or familiarization program. The latter program should be designed to ensure that the teacher has an adequate overview of the curriculum materials and a general appreciation of the modular concept. Also, if possible, the teacher should be afforded an opportunity to dialogue with developers of the material, thereby resolving any variances between intended meaning and interpretation.

Staff assistants may be used in stock control to set out the proper equipment for laboratory classes, to keep equipment operating properly, to assist in the development of teaching materials, supervise laboratories, and do a limited amount of routine paper grading and project checking.

By adjusting the size of the supportive staff to the demands of enrollment, a school may partially solve the problem of staffing instructors when it is necessary to teach a number of different courses in one term. Supportive staff members may be recruited from the student body or from graduates of the program.

New approaches to the organization of faculty should be considered. Team teaching is one possible approach. In this sense, team teaching is the organization of a technical staff into a coordinated teaching unit. Teaching assignments are made on the basis of the individual member's special training and talents. Team planning allows for concurrent courses to be closely coordinated by team members to best utilize the student's time while the student is moved smoothly to progressively higher levels.

A weekly departmental staff meeting to encourage and sustain team teaching efforts is recommended. At these meetings, team members can assess and evaluate progress and plan on the basis of this evaluation and on current developments. This is especially important when a new course or a new technique is involved.

In addition to coordinating concurrent courses, staff meetings provide for free exchange of ideas on teaching techniques discovered to be useful and on recently developed laboratory projects which seem to be particularly successful.

To help keep a staff effective, an in-

stitution should encourage all staff members to up-date their knowledge of current industrial practice. Their knowledge of teaching techniques and innovations in education must continue to grow and expand. Membership in professional and educational associations should be encouraged, together with active participation in professional association work at local, state, regional and national levels. Through such organizations, faculty can keep up with new literature in the field and maintain closer liaison with employers.

Close contact with employers will also ensure success of the program through the following areas:

- Employment of graduates.
- Opportunities for cooperative programs.
- Assistance in organizing and presenting short courses and conferences.
- Donations of equipment and scholarships.
- A viable industrial advisory committee.

STUDENT SELECTION AND SERVICES

Preparation of functionally competent nuclear instrumentation and control technicians makes three major demands upon the training program: 1) the training should equip graduates to take an entry job in which they will be productive; 2) it should enable graduates to advance to positions of increasing responsibility after a reasonable amount of experience; and 3) it should provide a comprehensive foundation to support further study.

Students entering the program should have certain capabilities, including comprehension and knowledge of underlying subject areas and related skills, and adequate study habits and language competencies.

Emotionally unstable individuals and habitual users of drugs and alcohol are generally considered not to be sufficiently reliable for the demanding responsibilities of nuclear reactor operation.

The program described in this Guide is designed for the typical average student (high school graduate or equivalent with one year of math and one basic science course); however, ability levels of those who enter the program generally vary greatly. Many students, whose intelligence and interest make them capable of mastering the curriculum required in the program, have under-developed scholastic skills. If applicants for admission to the program do not have the necessary scholastic background and skills, they should be given an opportunity to enter an organized program for the development of prerequisite skills before entering the technical program. This would ensure them a good probability of successfully completing the technical program. The institution should provide developmental programs to give students this opportunity.

Personal interviews with prospective students for the purpose of effective guidance and counseling are essential. Students should be given interest and aptitude tests by the guidance and counseling departments of the institution to assist them in selecting educational and occupational objectives consistent with their interest and abilities. This will assist them in determining their career objectives and selecting the programs appropriate to their interests.

Students should be given a thorough orientation program upon entry to the institution. This program should include an orientation to the facilities available on the campus, including the student lounges, dining areas, bookstores and recreational facilities. In particular, they should be given a comprehensive tour of the library to familiarize them with its various facilities and procedures and rules governing its use.

Students should be provided information regarding student membership in technical and professional organizations, locally, statewide, and nationally, and encouraged to join such

organizations. Membership in professional organizations provides students with an opportunity to receive excellent material on a regular basis at a substantial reduction in cost, to associate with other people in the field at meetings and to develop a habit of regularly reading journal articles to keep their technical knowledge in the field current.

Graduates of the program should be aided in every way in finding suitable employment. Placement of graduates is an important and multifaceted responsibility involving the placement department, the department head and instructors, and, either directly or indirectly, the advisory committee. However, the primary placement responsibility in new and changing technologies should rest upon the department faculty. They should send out announcements of upcoming graduates to the respondents of the needs survey and to committee members. Outstanding and successfully placed graduates and their employers are the most effective advertisers of the program.

The institution should conduct periodic follow-up studies of graduates to improve curriculum and teaching techniques, evaluate training effectiveness, maintain good employer-employee relationships, and provide a continuing evaluation of the total program.

FACILITIES

Industrial training programs vary widely according to need – from classrooms in a plant to sophisticated, specialized training centers; therefore, this discussion applies more specifically to institutional planners whose needs may be standardized to some extent.

For institutions, facility requirements of approximately 2000 square feet include the usual classroom(s), laboratory(ies), storage area(s), and staff office(s). Whenever possible, these areas should be combined in a single building for efficiency, economics and safety.

The following discussion assumes a class size of twenty-four students with two lab sections for each class. Thus, the classroom illustrated accommodates twenty-four to thirty students comfortably. The storage space included is adequate for audio-visual equipment and other materials normally required for classroom instruction.

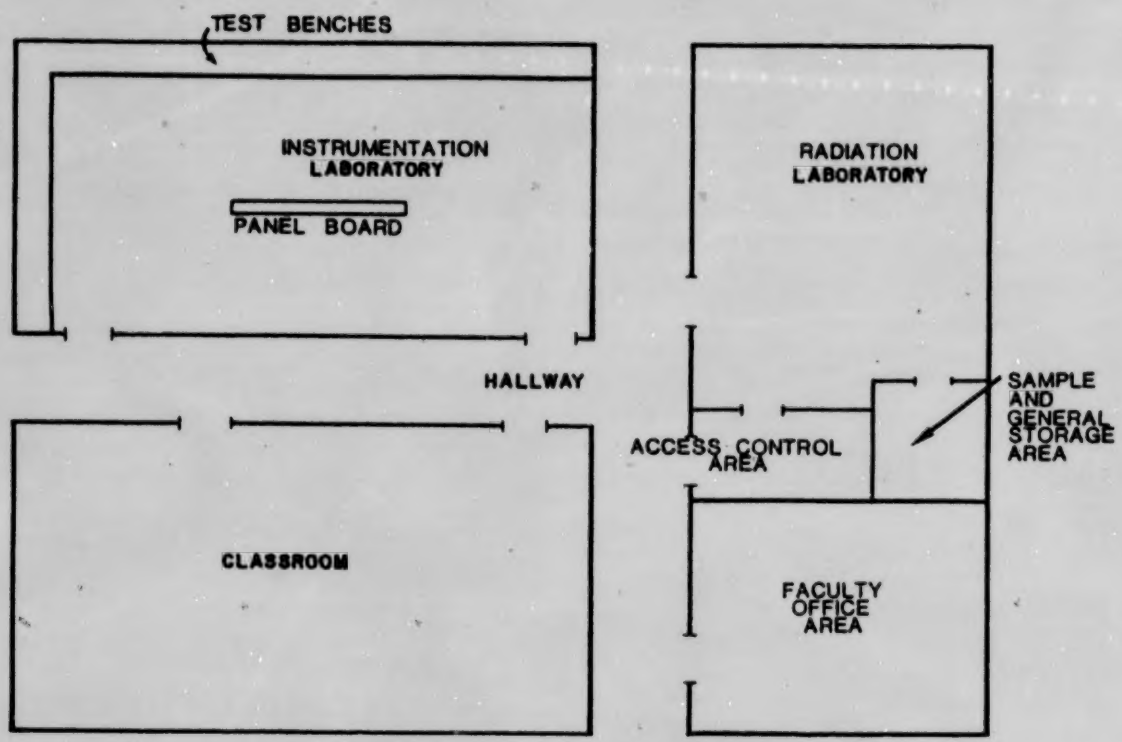
A typical laboratory layout shown on page for implementation of the complete curriculum would include all the elements shown; however, options offered as adjuncts to existing programs may adapt nuclear instrumentation equipment to electronics or physics laboratories.

Two laboratories should be considered: 1) a general nuclear laboratory with radiation detection and counting capabilities and 2) instrumentation repair and service laboratory. As much as is possible, instruments must be kept free from contamination by radiation samples.

General laboratory stations should provide ample table area for radiation counting equipment and work space for students' notebooks and charts. Stations should be designed for handling and storing radionuclides and small radioactive sources in a workbench-type layout. Counter tops and sinks (with hot and cold water taps) should be of stainless steel for easy decontamination and cleaning. Storage drawers should be leadlined. Key-locks should be installed to minimize unauthorized access.

A storage area adjacent to the radiation laboratory should include an accountability area for the storage of radioactive materials and contaminates. (Note: A system of accountability provides students with realistic, on-the-job type procedures.) Also, in this area, there should be a workbench and central tool storage.

If possible, the main instrument laboratory should be on the ground floor where there is a solid foundation for a drill press and grinder, where suitable floor drains can be installed, and where moderately heavy items



SUGGESTED FACILITIES FLOOR PLAN
FOR INSTRUMENTATION AND CONTROL

can be received or dispatched conveniently. A classroom near the instrument laboratory is also desirable. All classrooms and laboratories should be well lit with a recommended minimum of 50-footcandles of light at tables or desk tops. Fluorescent lighting is satisfactory.

Hot and cold water, compressed air, and steam service lines to instrument laboratories should be planned for the shortest length of piping consistent with laboratory arrangement. Filtered air should be used for instrument laboratories. Pipes should be hidden as much as possible, but control points should be planned for safety, accessibility, and ease of maintenance. Each laboratory should have a master control panel with shut-off valves for each utility; this panel should also have a door with a lock on it so utilities can be controlled at a central point and locked up.

Electrical lines should provide both 110- and 220-volt, single-phase electrical service for instrumentation laboratories. Most equipment used in the laboratory requires 110 volts; occasionally 220-volt, single-phase current is required.

When electrical service is connected to laboratory test benches, each bench should be connected to a separate circuit breaker, and the circuits should be designed with ample capacity so that when a number of students

are using electrical apparatus at the same time the lines will not become overloaded. Each laboratory should have a separate master distribution control panel for electrical circuits.

Staff office space differentiates between department head and instructor(s), and places one person in each office to allow for personalized counseling.

Though new facilities may normally be acquired through established appropriation channels, some schools qualify for various special State and Federal grants. These should be explored by each school's grants department or personnel.

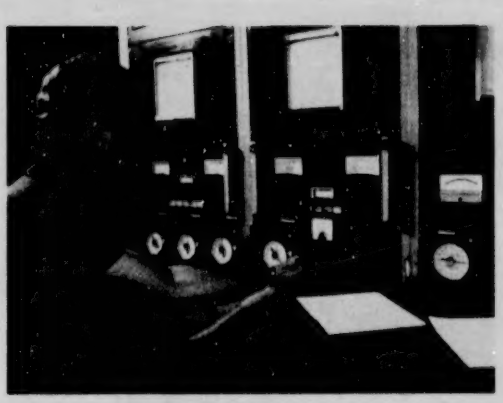
EQUIPMENT

Proper training of technicians for industry entails hands-on experience with industrial-type equipment, insofar as is practical. All unique items of equipment necessary for a viable program in nuclear instrumentation and control training are listed in Appendix E. This list incorporates specific items called out in each module and includes special nuclear laboratory storage and handling equipment.

Each item of equipment is accompanied by a recommended quantity, based on requirements of one class of twenty-four students divided into two laboratory sections of twelve students each. Cost approximations, based on 1979 vendor catalog prices, follow each listing.

The equipment list (Appendix E) includes unique items identified by authors of the curriculum materials as necessary or desired equipment for carrying out procedures included in the modules. (Note: Equipment should be equivalent to that used in industry whenever possible.) Ordering information is included with the equipment list.

Not included in the list are such items as visual and audio aids and models. Such materials are available commercially and from industry public relations offices. Simulators



Technician with instrumentation equipment.

of instrumentation and control systems can be designed and built, for limited use, at a cost of a few thousand dollars, or purchased at costs ranging from hundreds of thousands up to five million dollars and more. Usually, access to a research reactor (for institutional training) or a working reactor (for industrial training) can be arranged to permit familiarity with such instrumentation equipment. A list of university research reactors is found in Appendix D. Also, used equipment and materials can provide excellent teaching aids. In industry-sponsored training programs, such equipment may be obtained from stock; institutions may need to look to industry – especially their industrial advisory committees – for contributions of used equipment.

LIBRARY

In each module, a list of reference materials is included. For the convenience of each institutional or industrial program developed, a suggested list of references and periodicals is presented in Appendix F.

Dynamic developments, causing rapid changes

in technological science and practice, make it imperative that students learn to use a library. Instructions for technology students should include assignments that require them to use the library so that they may form the habit of using the library as a tool in learning. This knowledge helps students develop professional attitudes and further teaches them to depend on libraries to keep abreast of new developments.

Reference materials and related media materials for teaching the technology should be reviewed continuously and revised or replaced, keeping in mind 1) the rapid development of new knowledge, techniques and procedures in the field, 2) the results of research in methodology of teaching in the field of nuclear technology, and 3) the dynamics of change within the structure and philosophy of nuclear industry. It is mandatory that instructors constantly seek and review new references and related media materials as they become available, and adopt those that are an improvement over those suggested in this Guide (Appendix F), or those currently in use.

Instructors of all courses should inform their students that library use is an important part of the program. Planned assignments that require the use of a library to research additional facts and new techniques on pertinent subjects enable students to understand the resources available and their relation to technology. Open-book examinations that require use of a library provide excellent, objective experiences. Under the incentive of such examination, and the pressure of time, students obtain clear understandings of their own competencies in library use.

The growth and success of a graduate technician depend largely on an ability to keep up with changes in the field.

Library content may be classified as basic encyclopedic and reference index material, reference books pertinent to nuclear technology, relevant periodicals and journals, and audio-visual aids.

Therefore, a central library, under the direction of a professional librarian, is important to the success of a technology program. Most instructors have private libraries in their offices from which they may select books of special interest to discuss in their personal conferences with students, thereby stimulating interest in related literature; however, a central library ensures acquisition and cataloging according to accepted library practices, and provides systematic card files, which facilitate the location of reference materials. It also provides a controlled and orderly system for lending books to students, typical of a system they might encounter as employed technicians. Provisions for lending materials for out-of-library use should be systematic and efficient. Suitable study space should be provided for students for use of references.

A limited library incorporating books referenced in the curriculum material, supplemented by appropriate specifications (e.g., 10CFR50, ASME Boiler and Pressure Vessel Code, etc.) and relevant trade journals, should be maintained in the instructional area.

COST

The information given in Appendix E affords curriculum planners adequate data for estimating equipment costs based on 1979 prices; however, once a tentative equipment list is developed, planners are urged to contact appropriate distributors (from their own associations or from the vendor list provided in Appendix E) and obtain definite price quotes.

Equipment is only one cost that should be predetermined. Facility cost includes the classroom, laboratories, offices and associated areas. It includes furnishings, utilities and

maintenance. In most schools and industrial facilities, these items are determined on a pro-rata basis.

The cost of supplies – used in the offices as well as in the classroom and laboratories, including handouts, preprinted tests and visual aids – should be estimated as accurately as possible.

Faculty and staff costs are a significant item. The costs of field trips and faculty travel and participation in industrial advisory committee meetings, technical associations and their activities, and special seminars should be anticipated.

Making determinations of program costs becomes meaningful when decisions must be made as to 1) whether or not the program is affordable, 2) whether or not the program will be cost effective and 3) whether or not to implement the program.

To provide the program developer with a rationale for developing cost data, sample calculations are presented in Appendix G. Sample Calculation No. 1 assumes a full class – ongoing program – having department head and a full-time instructor. Calculation No. 2 assumes a typical first-year start-up program; one instructor who also acts as the department head and a minimum number of students. These calculations must not be accepted as accurately reflecting a given situation, but only as guidelines from which a program planner may extract appropriate techniques. Note that all cost estimates (including faculty) attempt to reflect both appropriation and budgetary items (for schools).

The final calculation in Appendix G applies to industry only.

PROGRAM IMPLEMENTATION AND EVALUATION

The level of effort involved in implementing a new program of instruction may vary from one setting to another, but the essential elements remain fairly constant.

IMPLEMENTATION

Implementation includes:

- Identifying needs.
- Determining curriculum requirements.
- Preparing and presenting program proposal, obtaining approval.
- Selecting and preparing staff.
- Acquiring facilities and equipment.
- Enlisting students.

LOCAL/REGIONAL NEEDS ASSESSMENT/ANALYSIS

Determination of needs consists of three steps:

Identification of employers:
- (both present and potential).

Identification of jobs.
- Task inventory.
- Entry-level requirements.
- Employment projections.

Analysis of Needs:
- Benefits versus expenditures.

A listing of employers should be available to interested schools. Local identification of such employers can be achieved readily with the counsel of a well chosen industrial advisory committee, many of whom will be employers (or representatives of employing organizations) of nuclear operators and technicians.

With the assistance of the committee and local employers, the several aspects of job identification can be successfully completed in a relatively brief period of time. Usually, this step can be carried out by mail, utilizing properly prepared survey instruments, examples of which are presented in Appendix C.

Any new program should be self-justifying. The benefits should justify the cost. Factors entering into this analysis include:

- Quantity of job opportunities.
- Quality of job opportunities.
- Projected job opportunities.
- Capability of institution to offer program:
  - Budget.
  - Facilities.
  - Faculty.
  - Administrative fervor.
    (Without an administrative commitment, no program is apt to evolve, even though all other elements are present.)

The industrial advisory committee's experitise should be utilized in this analysis of needs. Each member should be given an opportunity to review and evaluate the cumulative results of the needs survey and the school representative's assessment of the institution's capabilities. They may be able to suggest or propose ways of overcoming certain weaknesses or shortcomings.

CURRICULUM REQUIREMENTS DETERMINATION

Because curricula must be responsive (in technical education) to the real needs of technological industry, any determination of curriculum requirements must come after a realistic assessment and analysis of industrial workforce needs. The modular curriculum suggested in this Guide for training nuclear operators and technicians can be adopted wholly or in part to meet the real needs of industry. The materials to be used should be selected with care and, preferably, with the consultation of committee members to ensure compatability with industrial needs.

Personnel, familiar with the materials, content and sequencing and experienced in the

matching of the curriculum to needs, should be utilized in developing the program. Members of the industrial advisory committee, with knowledge of workforce training needs, should assist in the reviewing and selecting process.

Technical education must meet industry needs.

Once program implementation reaches this development point, a formal proposal – in most institutions – must be prepared and presented to appropriate administrators, boards and agencies.

PROGRAM PROPOSAL PREPARATION

Three criteria should be satisfied in presenting a successful proposal for a new technical education program.

Need (for program). This criteria should have been established by the needs assessment and analysis. All data, both supportive and detractive, should be included along with letters or directly quoted comments and opinions of industrial advisory committee members.

Capability (of institution to provide program). This criteria includes: 1) fair and comprehensive evaluation of a school's interest in the program (top executives and/or administrative support and faculty enthusiasm), 2) its budgetary potential (requires a good estimate of program's cost and enrollment potential), and 3) its available facilities.

Cost effectiveness. There are two approaches to this determination: 1) immediate effectiveness – whenever possible, a program should be self-sustaining. Thus, it is important to establish program cost versus direct economic return. All the inputs that go into making this determination, including a realistic projection of enrollment in the program, should be incorporated into this proposal; 2) long-term effectiveness – total effect of the program on school resources should be weighed against benefits to society. In many instances, these determinants must be stated in intangible terms. Even so, they should be presented fairly and as accurately as possible.

PROPOSAL FORMAT

The format of the proposal varies extensively from school to school; however, as a general rule any proposal should be straightforward, concise and simply stated as its preparer can make it. The following elements are meant only to imply a possible outline.

- Preface. (What the document is; who prepared it; for whom was it prepared?) No more than one (1) page.
- The Need. Reflecting all items discussed earlier.
- The Curriculum.
- The Plan. Organizational approach; facilities utilization; human and financial resources.
- The Cost.
- The Benefits.
- The Recommendations. Based on reasonably drawn conclusions.
- Letters/documents of support.
- Evaluation of existing compatible programs.

Once a program has received formal approval, instructional preparation becomes an immediate consideration.

EVALUATION

Human endeavor is subject to continual evaluation, generally informal, but evaluation nonetheless. It is this ongoing monitor-review activity that guides any individual or corporate activity to ultimate success – success that can only be assessed in retrospect. An educational program – human endeavor of a corporate nature – should also be evaluated progressively (as well as on the basis of its end product) to ensure its constancy toward the development of a successful end product.

CURRICULUM ACCEPTANCE

While a major evaluation factor is adequate enrollment, other criteria provide significant, if not major, evaluation tools:

- Drawing power and holding power of program. Does program attract and hold qualified students in a manner comparable with similar technical programs?
- Student enthusiasm and morale. Is there an observable esprit de corps within the classes or groups of students enrolled in the program?

Enrollment figures (compared with similar technical programs or with enrollment goals or limitations) answer the first question. The second may require a more comprehensive evaluation. For example, student response to a program may be evaluated subjectively by adjudging such factors as:

- Interest/disinterest in classroom activities, laboratory procedures and homework or outside study (based on attentiveness and actions).
- Enthusiasm/indifference as related to the total program (based on attendance).
- Test scores on materials that judge student's progress in assimilating skills and knowledge essential for technical employment.

More commonly, however, evaluation tools are employed to reflect the students' responses more directly. This objective evaluation procedure (from the faculty's standpoint), which employs one or more questionnaires, seeks responses in the following areas:

- Teacher effectiveness (including lab instructors).
- Materials applicability (including understandability and program content relevance).
- Facilities and equipment adequacy.
- Student self-evaluation (including attitude, progress and continued interest.

GRADUATE PERFORMANCE

The ultimate evaluation of a technical education program stems from the success of its graduates:

- Do their skills and knowledge meet entry-level requirements?
- Are they successful in the job market?
- Does their on-the-job performance satisfy employer expectations?
- Are they promotable?

These questions may be asked of both the graduates and their employers. (Placement records may be more indicative of a hungry job market than a successful training program; therefore, evaluation should go beyond this initial transition from student to employee.)

Graduated students, along with their employers, should also be asked to reflect upon or review the training program periodically. This means of relating program content to occupational needs should prove especially valuable in incorporating new or updating technological developments into the program.

APPENDICES

APPENDIX A

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APPENDIX B

TECHNICAL SPECIALTY COURSES AND MODULE TITLES AND DESCRIPTIONS

COURSE 1, RADIATION PHYSICS.

Module 1-1, "Introduction to Radiation Laboratory Safety."

This module examines basic radiation safety terms including: radioactivity, radiation, agreement state, monitoring radioactive waste and decontamination. Guidelines are also given which provide a method for developing specific laboratory rules relating to radiation safety.

Module 1-2, "Basic Radiation Detection and Measuring Equipment."

Included in this mdoule is a description and discussion of the function of (a) ionization, (b) film badge, (c) dosimeter, (d) scaler, (e) ratemeter, and (f) count-rate.

Module 1-3, "Atomic Structure and Radioactivity."

This module includes basic principles of atomic structure, definition of elements and atoms, and a description of the Geiger-Müeller plateau. Each topic is illustrated with labeled diagrams.

Module 1-4, "Radioactive Decay and Half-Life."

Radioactive decay and half-life are described through the definition of (a) radioactive decay, (b) stability, (c) nuclear force, (d) electrostatic force, (e) half-life, (f) decay constant, (g) activity, (h) specific activity, (i) Avogadro's number, (j) curie, (k) nucleon, (l) gram-atomic weight, and (m) atomic weight.

Module 1-5, "Radioactive Decay Processes and Schemes."

Several aspects of particulate radiation are described including particle speed, mass in AMU, electrical charge and penetrability. Sample decay equations and decay schemes for given decay processes are illustrated. Instructions are also given for reading and interpreting the Chart of Nuclides.

Module 1-6, "Basic Properties of Gamma Radiation."

This module includes a basic description of gamma radiation and its properties.

COURSE 2, RADIATION PROTECTION I.

Module 2-1, "Radiation Exposure and Absorbed Dose Values."

This material involves a study of radiation exposure and absorbed values by defining the limits of usage for the units of radiation dosage, teaching rapid conversion from all systems of units into rem and explaining why quality factor is different for different types of radiation.

Module 2-2, "Biological Effects of Radiation."

The biological effects of radiation including: mechanisms by which radiation damages living body cells, typical radiation syndrome, differentiation between internal and external radiation exposures are presented. Also included is a discussion and evaluation of the hazards of biological injury to the general population versus that to the radiation worker and an explanation of the benefit versus risk concept in the use of radiation.

Module 2-3, "Radiation Protection Standards."

Initially this module examines the radiation protection standards associated with dose level exposures for accumulated whole body, extremities and skin. The correct completion of all applications and report forms required by state and local standards pertinent to radiation protection and establishment and maintenance of record systems that facilitate compliance with the regulations are also included.

Module 2-4, "Internal Dose Calculations."

Various methods of internal dose calculation are discussed including: MCP, body burden, standard man, bioassay, ICRP, critical organ, handbook 69, effective half-life, empirical, smear, RBE, radiosensitivity, ash sample, one-shot intake.

Module 2-5, "Personnel Monitoring Devices, Ionization Types."

This module contains a detailed look at the ionizing type personnel monitoring devices. The two common types of dosimeters are illustrated, their structure examined and the mechanisms for charging and reading the dosimeter is discussed. The precautions and limitations to be observed in using dosimeters are also listed.

Module 2-6, "Personnel Monitoring Devices, Chemical Types."

Chemical types of personnel monitoring devices are looked at in detail. Five different types are examined as to their ability to detect ionizing and neutron radiation, basic operational feature, relative accuracy and speed of use. Guidelines are also provided for the selection of the most practical types to be utilized under given radiation monitoring situations.

COURSE 3, PRINCIPLES OF PROCESS INSTRUMENTATION.

Module 3-1, "Temperature-Sensing Devices: Glass-Bulb Thermometers."

The glass-bulb thermometer as a basic temperature sensing device is discussed as to its operational theory, variety and ability to monitor temperature.

Module 3-2, "Temperature-Sensing Devices: Thermocouples."

This module discusses in detail the operational theory of thermocouples and temperature measurement systems utilizing thermocouples.

Module 3-3, "Temperature-Sensing Devices: Resistance Thermometers."

A detailed presentation concerning the theory and operation of resistance thermometer systems is given.

Module 3-4, "Temperature-Sensing Devices: Pyrometers."

The temperature measuring qualities of an optical pyrometer are listed, and its design and optimum use are detailed.

Module 3-5, "Basic Principles of Flow Measurement."

This module studies the principles of flow and pressure and measurement of each using the proper instruments.

Module 3-6, "Pressure-Sensing Devices."

This module examines the operating characteristics and use of several manometer and mechanical gage type pressure-sensing devices. The devices are compared and contrasted and their optimum use described.

Module 3-7, "Flow-Sensing Devices: Differential Pressure Flowmeters."

The specific characteristics, applications, advantages and disadvantages, installation and maintenance of differential-pressure flow measurement devices are discussed. The terminology related to calibration of the devices is also covered.

Module 3-8, "Flow-Sensing Devices: Linear Flowmeters."

Basic operating principles of primary elements of linear flowmeters and related secondary elements are discussed. The specific characteristics, uses, advantages and disadvantages, installation, alignment (calibration), operation and maintenance are discussed for power plant applications.

COURSE 4, HEAT TRANSFER AND FLUID FLOW.

Module 4-1, "Basic Properties of Fluids."

This module gives a basic introduction to matter and its properties. The various temperature scales, measurement of density, specific weight, buoyancy and viscosity are some of the properties of fluids that are discussed. Energy movement is also discussed in the law of heat exchange, specific heat, heat of fusion and meeting and vaporization.

Module 4-2, "Fluid Statics."

Several aspects of pressure related to fluids are illustrated and examples of related calculations given. The characteristics of force and pressure, pressure in liquids at rest, principles of hydraulics and pressure calculations on submerged bodies are also provided.

Module 4-3, "Fluid Dynamics."

The topic of fluid dynamics is examined through the discussion of the venturi meter, Bernoulli's principle, and the Reynolds number. Other effects on fluid systems discussed include friction and other causes of pressure loss.

Module 4-4, "Heat Transfer by Conduction."

This module discusses the one of three methods of heat transfer, namely conductivity. Units used to describe heat transfer are defined as are specific heat, heat flux and atomic action. A tabular comparison of the conductivity of several materials is also presented.

Module 4-5, "Heat Transfer by Convection."

A second type of heat transfer by convection is described in detail. Natural and forced convection are discussed with details of calculating forced convection under given circumstances presented. The convection current patterns created by expanding fluids in a confined area are also described.

Module 4-6, "Heat Transfer by Radiation."

The phenomenon of thermal radiation as another mechanism of heat transfer is described. The electromagnetic radiation emitted by a body as a result of its temperature is calculated. Thermal conductivity of several building materials is listed and discussed. A comparison between a black body absorber and a white body emitter is described.

Module 4-7, "Change of Phase - Boiling."

This module gives a brief description of the states of matter and their inherent characteristics. Enthalpy and entropy as thermodynamic properties are also discussed. Included also are calculations of the quality and void fraction properties of a liquid, and, finally, a description of five types of boiling are provided.

Module 4-8, "Burnout and Flow Instability."

The mechanisms for calculating critical flux, DNB and DNBR are described as well as detailed descriptions of how burnout and flow instability are detected in reactor systems.

Module 4-9, "Reactor Heat Transfer Limits."

Heat transfer limits are discussed by examining fuel rod design and characteristics, limiting design factors of the reactor and calculating critical heat flux given certain conditions. Power output is also described as it pertains to radial and axial power distribution, peaking factors and critical heat flux ratios.

COURSE 5, INTRODUCTION TO NUCLEAR SYSTEMS.

Module 5-1, "Basic Nuclear Reactor Components."

Sketches and diagrams are used to illustrate and discuss the components of a light water reactor, reactor vessels, control rod drive systems (PWR and BWR) and fuel assemblies in PWR and BWR systems.

Module 5-2, "Pressurized Water Reactor (PWR)."

This module gives a detailed look at a pressurized water reactor (PWR) including the hydraulic, pneumatic and electrical components. Diagrams and illustrations show their internal structures, and the two basic types of steam generators are illustrated and discussed.

Module 5-3, "Boiling Water Reactor (BWR)."

The boiling water reactor (BWR) is described in detail including its advantages and limitations. Illustrations clearly describe the various systems and components of the BWR. Fuel assemblies, control rods and jet pumps are also described in details.

Module 5-4, "Primary Cooling Systems."

A brief review of the reactor vessel, pressurizers and steam generators is provided. Detailed mechanisms and design characteristics of reactor coolant pumps, piping, primary systems, valves and insulation is also shown. Overall design specifications and in-service inspection is also discussed.

Module 5-5, "Nuclear Instrumentation."

This module describes in detail the types and components of radiation detectors used to monitor radiation levels in power plants. Four kinds of radiation and associated instruments are listed and discussed as well as back up or fail safe systems for monitors.

Module 5-6, "Nuclear Fuel Cycle."

The complete nuclear fuel cycle is illustrated and described in detail through the following steps: (a) mining, (b) milling, (c) refining, (d) enriching, (e) oxide fabrication and (f) fuel assembly through reprocessing spent fuel. Plutonium and thorium are also introduced as potential fuels for the future. A visit to a plant involved in one of the steps in the cycle is encouraged.

COURSE 6, INSTRUMENTATION AND CONTROL OF REACTORS AND PLANT SYSTEMS.

Module 6-1, "Neutron Monitoring Systems."

Electrical output is measured as a function of neutron activity in power plants, consequently, the monitoring of the level of neutron activity is described in great detail. Definitions of source range, intermediate range and power range are given, and the monitoring techniques for each are examined.

Module 6-2, "Neutron Sensors."

The mechanics of operation of gas-filled neutron detectors is reviewed in this module. Also described and illustrated are a fission chamber, boron proportional counter, compensated ion chamber, uncompensated ion chamber and neutron thermopiles.

Module 6-3, "Neutron Flux Signal Conditioning."

This module examines electrical output characteristics of neutron detection devices and how pre-amp circuits are used to process the information prior to display. Methods of detector signal analysis and conditioning used to monitor nuclear flux are also presented.

Module 6-4, "Control-Rod Drives and Indicating Systems."

A key to the operation of a reactor is its mechanisms associated with the control rods which are explained in detail through discussions of nonsolid and solid control element systems, shapes and materials of control rods and the different methods of control-rod drives. The module also discusses the system most common to PWR and BWR applications.

Module 6-5, "Instrumentation Power Supplies."

Schematic diagrams of reactor power supplies are given in this module. Passive and active power supply filters are also described and illustrated.

Module 6-6, "Installation of Instrumentation Systems."

Several aspects of instrumentation installation are covered in this module including descriptions of the four categories of instrument systems, instrument system standards and components, installation steps and techniques and system inspection. A final discussion centers around quality assurance and quality control in reactor power plants.

COURSE 11, RADIATION DETECTION AND MEASUREMENT.

Module 11-1, "Statistics of Radiation Counting."

Radioactivity follows certain predictable patterns which are statistically described through the definitions of (a) radioactive decay, (b) geometry factor, (c) interactions, (d) inverse-square law, (e) dead time, (f) average value, (g) standard error, (h) theoretical standard deviation, (i) standard deviation, and (j) normal distribution. Background radiation and changes in counter geometry are also discussed.

Module 11-2, "Gas-Filled Detectors I: Ionization Detectors."

Three types of ionization detectors including the integrating, nonintegrating and mean-level are described. The module also describes the calculation of current produced by given exposure, ionization chambers and curves, and the details of a pocket dosimeter. Other terms defined in the module include: (a) pulse counter, (b) ion pair, (c) recombination, (d) saturation voltage, (e) saturation

current, (f) discriminator, (g) air equivalence, (h) energy dependence, (i) spectroscopy, and (j) efficiency.

Module 11-3, "Gas-Filled Detectors II: Proportional Counters."

This is the second module in a series discussing detectors and describes proportional counters – the five basic types and varieties. Definitions found in the module include: (a) P-10 gas, (b) internal proportional counter, (c) 4π or absolute counter, (d) flow-through counter, (e) discriminator, (f) resolving time, (g) fission counter, (h) proton recoil counter, (i) Hurst counter, and (j) Hurst dosimeter.

Module 11-4, "Gas-Filled Detectors III: Geiger-Müeller Counters."

This is the third module in the detector series and specifically describes the operating mechanisms of a gas-filled detector using the Geiger counter as an example. Terms discussed and defined include: (a) internal and external quenching, (b) limited proportionality, (c) break-down voltage, (d) continuous-discharge region, (e) multiple discharge, (f) dead time, (g) recovery time, (h) geometry factor, and (i) self-absorption.

Module 11-5, "Scintillators, Semiconductors and Spectroscopy."

Another class of detectors includes the solid-state devices discussed in this module including the four basic types of scintillation counters and the three categories of semiconductor devices. Also covered are such terms as: (a) photomultiplier tube, (b) luminescence, (c) phosphorescence, (d) activator, (e) photocathode, (f) dynodes, (g) secondary emission ratio, (h) well crystal, (i) p-n junction, (j) depletion layer, (k) GeLi detector, and (l) pulse-height analysis.

Module 11-6, "External Personnel Dosimeters for Beta-Photon Monitoring."

Two major types of dosimeters (namely, photographic and luminescent dosimeters) are discussed and illustrated including the mechanisms for calibration, limitations, and optimum use. Several other items are described including: (a)roentgen, (b) rad, (c) rem, (d) quality factor, (e) latent image, (f) sensitivity, (g) energy dependence, (h) radiophotoluminescence, (i) thermoluminescence, (j) glow curve, and (k) glow peak. The effect of radiation dose is also briefly discussed.

Module 11-7, "Neutron Detectors, Dosimetry and Activation Analysis."

Three major groupings of neutron detectors and their applications are described and the details of a compensated ionization chamber, activation foils, the albedo neutron dosimeter, and a fission-fragment dosimeter are included. Neutron activation analysis is also introduced and briefly described.

Module 11-8, "Radiological Calibration and Standardization."

This module examines five aspects of radioactive standardization including: (a) measurement of disintegration rate, (b) mass determination, (c) calorimeter, (d) source preparation, and (e) standardized solutions used. Common radioactive standardization sources are discussed and requirements of the National Bureau of Standards also are outlined.

COURSE 12, REACTOR PHYSICS.

Module 12-1, "Neutron Physics."

Five major topics are covered in this module starting with an identification of neutron sources followed by a description of the classification of neutrons, neutron flux and fluence, neutron detection and finally neutron survey meters.

Module 12-2, "Cross Sections and Reactions."

Many neutron interactions are possible during the fission process, and the possibilities and probabilities through the concept of cross section are described. The application and methods of measurement of cross section is also listed. Introduction to the basic laboratory procedures demonstrating absorption, attenuation, thermalization and activation is also provided.

Module 12-3, "Fission Rate and Reactor Power."

The discovery of the process of fission is described in this module followed by discussions of thermal neutrons, fission fragments, fission neutrons, origins of fission energy and spontaneous fission. Several terms introduced in the module include: (a) transuranium elements, (b) fissile, (c) fertile materials, (d) fission yield, (e) unsymmetrical yield, (f) decay heating, and (g) spontaneous fission.

Module 12-4, "Time Independent Nuclear Theory."

Subcritical, critical and supercritical reactor conditions are defined as well as a description of neutron flux, four and six factor formulas, subcritical multiplication and critical mass. The following list of terms is also used in the explanation of these concepts: (a) neutron generation, (b) multiplication factor, (c) thermal neutron, (d) fast neutron, (e) resonance region, (f) fissile material, and (g) fissionable material.

Module 12-5, "Time Dependent Nuclear Theory."

The time dependent nature of a reactor is examined in this module through kinetics and neutron flux, and by describing the activities of prompt and delayed neutrons and the in-hour equation.

Module 12-6, "Reactivity – Fuel Moderator and Control Systems."

An interrelationship exists between three critical components of a reactor, namely the fuel, control-rod system, and moderator which is described in detail. Their effect on the total reactivity of the plant is examined. Sound fuel management is also presented; and these key ideas are supported by the definition of core excess, heavy and light water, SCRAM, megawatt day, burnable poison and chemical shim.

Module 12-7, "Internal Effects on Reactivity."

This module examines the three basic factors – temperature, fission products and voids – which affect the final reactivity of a reactor proper. Reactivity coefficients are also defined and their effect on overall activity of the reactor is described.

Module 12-8, "Reactor Operating Characteristics."

The three basic reactor types including the PWR's, BWR's and GCR's are described as to their specific operating characteristics. Schematics are shown and summaries given of the number and types of reactors found in operation in the world.

COURSE 14, INTRODUCTION TO QUALITY ASSURANCE/QUALITY CONTROL.

Module 14-1, "Basic Requirements for Quality Assurance/Quality Control in the Nuclear Industry."

This module introduces the topic of QA/QC through a description of: (a) Federal regulatory processes, (b) an overview of QA/QC, (c) other participants in the licensing process, (d) the impact of technical professional organizations on QA/QC, and (e) a listing of the self-regulating mechanisms of the industry.

Module 14-2, "Definitions and Descriptions of Quality Assurance/Quality Control Criteria."

A concise definition of quality assurance and quality control and their differences are given in this module. The meanings of each of the eighteen QA criteria and basic duties of QA/QC personnel are also provided.

Module 14-3, "Governmental Regulation of Quality Assurance/Quality Control (AEC, NRC)."

The historical evolution of the AEC and NRC and their impact on nuclear regulation includes a discussion of Federal Regulation 10CFR50. Also included in this module is a description of the NRC rainbow-colored books which discuss various aspects of QA/QC. Finally, a brief description of the NRC regulatory guides is provided.

Module 14-4, "Technical Regulation of Quality Assurance/Quality Control (ASME, ANSI)."

Section III of the ASME code is examined in detail as is ANSI standard N45-2. The influence of ASTM, IEEE, ACI, and AWS on QA/QC is also given.

Module 14-5, "Implementation of Quality Assurance/Quality Control Programs and Procedures."

The parts of the QA/QC manual are described including minimum standards. A method of devising procedures and instruction documents and the contents of the ten parts is also provided. Finally, a note as to the functions of the QA/QC personnel is documented.

Module 14-6, "Application of Quality Assurance/Quality Control to Industry."

This module specifies the five requirements of 10CFR50, ASME code and ANSI standards for quality assurance/quality control which affect: (a) design aspects of materials, components and facilities, (b) manufacturing processes, (c) construction, testing and inspection, and (d) operation and maintenance for nuclear facilities.

Module 14-7, "Techniques and Variations in Quality Assurance/Quality Control."

Three QA/QC establishment procedures are described including user developed, consultant assisted, and subcontracted programs. Example forms are provided as indicators of typical tage sheets for QA/QC monitoring.

Module 14-8, "Quality Assurance/Quality Control Records and Documents."

Verification of QA/QC activities is handled through accurate, timely documentation of forms shown in this module. Selection of mechanisms for indexing, storage and retrieval of permanent and non-permanent records through the record control center is also discussed.

Module 14-9, "Special Studies in Quality Assurance/Quality Control."

General QA/QC requirements for technical and quality-assurance specifications are described. Several aspects of QA/QC personnel including: (a) certification, (b) on-the-job training, and (c) seminars, indoctrination programs, and orientations are also outlined. Briefly identified also are six methods of inspections, tests and verifications.

COURSE 33, CONTROL SYSTEMS I.

Module 33-1, "Introduction to Block Diagrams."

Upon completion of this module, the student should be able to represent a given system in block diagram form, define applicable terms, translate an algebraic equation into block diagram form, draw and label the canonical form of a feedback control system. The student will perform exercises in the use of block diagrams, representing physical systems, locate and simplify block diagrams in relevant publications such as periodicals, manufacturers' literature and other system descriptions.

Module 33-2, "Input/Output Devices."

Upon completion of this module, the student should be able to define applicable terms, describe the operation of selected transducers, describe input/output relationships for a linear potentiometer and determine the input/output relationship of at least three selected transducers. Laboratory determinations of input/out relationships for selected transducers will be completed.

Module 33-3, "Control System Theory."

Upon completion of this module, the student will be able to describe the objectives of a control system and discuss the operating characteristics of a system in terms of load changes, damping and stability. The student will observe a demonstration of an uncontrolled system, a marginally controlled system and an optimally controlled system. (The schematic and recommended parts list for an electropneumatic trainer that can be constructed by the school will be furnished.)

Module 33-4, "Pneumatic Control Mechanisms."

Upon completion of this module, the student should be able to discuss the theory of a valve type and Linear Aspirating Relays, locate the adjustment for reset/rate of response and pneumatic amplifiers given an electropneumatic control. Characterize modes of control for selected input/output relationships. Laboratory demonstrations of on/off, proportional, rate, integral and multimode operations of a controller will be included.

Module 33-5, "Control Valves."

Upon completion of this module, the student should be able to describe the operation of a pneumatic valve, draw typical characteristic curves of a control valve, determine valve position versus air signal relationship of a valve actuator, size of a valve from given parameters, and discuss valve selection. Students will conduct laboratories using valve selection specifications, equations, tables and nomographs for the selection of appropriate equipment.

Module 33-6, "Process Characteristics (Control Units)."

Upon completion of this module, the student will be able to discuss various modes of control. Practical exercises using the electropneumatic trainer will be conducted with the controller in various modes with different settings. The student will be able to discuss the characteristics of each mode for the processes demonstrated.

COURSE 34, CONTROL SYSTEMS II.

Module 34-1, "Introduction to Transfer Functions."

Upon completion of this module, the student should be able to determine from a given equation – resistance – capacitance – inertia or dead time elements, represent an algebraic equation using Laplace transformations from an input/output equation, express input/output relationships in the time domain, to the frequency domain. The student will conduct Laplace transforms to go from the time to the frequency domains. Given a mathematic relationship of the physical process, the student will be able to use Laplace transforms to obtain the step response and then graph it. The student will empirically determine the step response and the time constants of the process by graph method.

Module 34-2, "Frequency Response Analysis."

Upon completion of this module, the student will be able to draw a Bode diagram for a given transfer function of a single or multi component process. Given a frequency response (Bode diagram), determine the type of process in terms of transfer functions and their time constants.

Module 34-3, "Combination Control Systems."

Upon completion of this module, the student should be able to describe how a control loop or a control system maintains a dynamic process variable at an exact pre-determined condition. The topics covered include the following control types: cascade, ratio, adaptive, and feedforward.

Module 34-4, "Controller Tuning (Operational Checks and Adjustments)."

Upon completion of this module, the student will be able to outline the Ultimate Cycle, Process Reaction and Frequency Response methods of determining controller mode settings. Utilizing the electropneumatic trainer, demonstrate the use of one method for determining settings for one or more control modes.

Module 34-5, "Operational Amplifiers."

Upon completion of this module, the student should be able to describe an amplifier, draw a typical operational amplifier circuit, draw a block diagram from a linear differential equation using operational amplifier circuits. The student will construct operational amplifier circuits on "breadboards" using integrated circuits (IC), verify the theoretical input/output (IO) relationship of a summer, a comparitor and/or other operational amplifier circuits.

Module 34-6, "Microprocessor Utilization."

Upon completion of this module, the student will be able to describe how the microprocessor is used in the system control of a power plant and list the type of hardware used for different utilization. Set up a microprocessor system that simulates selected power plant system changes.

Module 34-7, "Microprocessor Programming."

Upon completion of this module, the student will be able to discuss and describe how microprocessors are programmed to meet power plant system needs and variations. Distinguish between control and computational applications of programming and describe the software requirements for each type of application. Using equipment constructed for Module 34-6, the student will perform simple power plant related programming.

COURSE 35, POWER PLANT ELECTRICAL SYSTEMS AND COMPONENTS.

Module 35-1, "Electrical Distribution."

Upon completion of this module, the student should be able to describe where a.c. and d.c. currents are used, plant arrangement of service buses and ESF's (Engineered Safety Features),

diesel generator systems and ESF for emergency conditions, battery and standby equipment, motors, generators, and motor control centers (MCC) for a typical power station.

Module 35-2, "Instrumentation and Control for Major Power Plant Components."

Upon completion of this module, the student should be able to describe the instrumentation and control (using necessary diagrams) for the following major plant components:

- Main turbines.
- Main electrical generator.
- Auxiliary power systems.
- Steam generator.
- Pressurizer.
- pH control of water system to reactor.

The student will prepare an instrumentation and control block diagram for an actual system and describe each major component function.

Module 35-3, "Recording and Display Devices."

Upon completion of this module, the student should be able to describe four different types of display devices and how they are used in the control circuits. List and describe the two different types of continuous recording devices used in instrumentation circuits. Include their relative advantages and disadvantages and how they are used in control circuits. The student will prepare a recommendation list with descriptive materials and drawings for several recording and display devices for the control circuit prepared in Module 35-2.

Module 35-4, "Process Control Loops and Devices."

Upon completion of this module, the student should be able to describe the objective of a control system (closed loop). Draw the basic control diagrams for two power plant systems, describe each component and what it controls. Dynamic behavior of the loop is presented. Student will visit a power plant, describe and trace through typical loop systems, prepare block and schematic diagrams, labeling major items.

Module 35-5, "Cathode-Ray Tube Systems (CRT)."

Upon completion of this module, the student should be able to describe the use of CRT's in power plant control rooms. Given a system from Module 35-2, the student should be able to prepare a diagram of a graphical display that might be used in a plant. Given a coded set of symbols, the student should list the codes to map the display.

Module 35-6, "Preventative Maintenance for Systems and Components."

Upon completion of this module, the student should be able to describe general inspection procedures including safety precautions. Documentation and scheduling methods are included, as well as elements of material control, planning, tagging, quality control and clearing. The student will prepare simple preventative maintenance (PM) schedules and write procedures for assigned equipment using the recommendations from Manufacturers' Manuals.

Module 35-7, "Instrument Reliability."

Upon completion of this module, the student should be able to describe pre-installation verification, installation procedures and checks, calibration of test equipment and preoperational testing. List and describe the major electrical standards and codes required and where they are applicable. The student will calibrate several instruments against a laboratory standard; for example, pressure, temperature and flow devices.

Courses being developed for the other curricula in the Nuclear Technology series (see chart on page 12) follow:

COURSE 7: REACTOR OPERATIONS.

Module 7-1: Reactor Operator Licenses.
Module 7-2: Administrative Control for Nuclear Systems.
Module 7-3: Reactor Operating Experiences.
Module 7-4: Reactor Startup Procedures.
Module 7-5: Pressurized Water Reactor Operating Characteristics.
Module 7-6: Boiling Water Reactor Operating Characteristics.
Module 7-7: Refueling of Reactors.

COURSE 8: REACTOR SAFETY.

Module 8-1: Introduction to Reactor Safety.
Module 8-2: Reactor Licensing.
Module 8-3: Reactor Protection Systems.
Module 8-4: Reactor Emergency Systems.
Module 8-5: Safeguards and Security.

COURSE 9: REACTOR AUXILIARY SYSTEMS.

Module 9-1: Containment and Ventilation of Reactors.
Module 9-2: Spent Nuclear Fuel Storage and Handling Procedures.
Module 9-3: Emergency Power Systems for Reactors.
Module 9-4: Residual and Emergency Cooling Systems for Reactors.

COURSE 10: POWER PLANT SYSTEMS.

Module 10-1: Power Plant Fundamentals.
Module 10-2: Power Plant Thermal Cycles.
Module 10-3: Turbines and Generators.
Module 10-4: Heat Exchangers and Condensers.
Module 10-5: Pumps.
Module 10-6: Valves and Piping.
Module 10-7: Electrical Transmission and Distribution Systems.
Module 10-8: Power Plant Fundamentals (Fossil Fuel Energy Efficiency).
Module 10-9: Fossil Plant: Auxiliary Discussions.

COURSE 13: POWER PLANT CHEMISTRY.

Module 13-1: Water Quality Control.
Module 13-2: Raw Water Treatment.
Module 13-3: Sources of Impurities in Reactor Water Systems.
Module 13-4: Water Treatment – Polishing by Ion Exchange, Evaporation and Demineralization.
Module 13-5: Water Properties Sensing.
Module 13-6: Water Analysis for Nuclear Power Plants.
Module 13-7: Radioactive Waste Handling – Liquid and Gaseous.

COURSE 15: METALLURGY AND METALS PROPERTIES.

Module 15-1: Fabrication Processes for Metals.
Module 15-2: Chemical Analysis of Metals.
Module 15-3: Basic Metallurgical Concepts.
Module 15-4: Properties of Steel.
Module 15-5: Metallographic Examination.
Module 15-6: Mechanical Testing – Tensile, Bend, Hardness.
Module 15-7: Mechanical Testing – Impact, Nick Break, Fatigue.
Module 15-8: Failure Mechanisms in Metals.

COURSE 16: MECHANICAL COMPONENT CHARACTERISTICS AND SPECIFICATIONS.

Module 16-1: Pump Characteristics and Specifications.
Module 16-2: Piping Characteristics and Specifications.
Module 16-3: Valve Characteristics and Specifications.
Module 16-4: Fastener Characteristics and Specifications.
Module 16-5: Lifting and Handling Equipment Characteristics and Specifications.
Module 16-6: Rotating Equipment Characteristics and Specifications.
Module 16-7: Heat Exchanger Characteristics and Specifications.
Module 16-8: Pressure Vessel Characteristics and Specifications.

COURSE 17: RADIATION PROTECTION II.

Module 17-1: Film Dosimetry.
Module 17-2: Thermoluminescent Dosimetry (TLD).
Module 17-3: Radiation Dose Assessment – Personnel Dosimeters.
Module 17-4: Internal Dose Assessment.
Module 17-5: Bioassay Techniques and Record Keeping for Radiation Protection.

COURSE 18: RADIOLOGICAL EMERGENCIES.

Module 18-1: General Procedures for Radiological Emergencies.
Module 18-2: Emergency Equipment for Nuclear Facilities.
Module 18-3: Surface Contamination – Decontamination.
Module 18-4: Criticality Control.
Module 18-5: Control of Radiological Hazards
Module 18-6: Emergency Planning for Nuclear Facilities.
Module 18-7: Emergency Drills for Nuclear Facilities.

COURSE 19: RADIATION SHIELDING.

Module 19-1: General Effect of Radiation Attenuation.
Module 19-2: Beta and Alpha Particle Attenuation.
Module 19-3: Neutron Attenuation.
Module 19-4: Gamma Attenuation.
Module 19-5: Background Radiation Reduction Techniques.
Module 19-6: Backscattering and Wall Scattering of Radiation.

COURSE 20: RADIATION MONITORING TECHNIQUES (RADIOCHEMICAL).

Module 20-1: Radiation Sample Preparation – Liquid.
Module 20-2: Radiation Sample Preparation – Solid.
Module 20-3: Air Monitoring Techniques – Particulate.
Module 20-4: Air Monitoring Techniques – Gaseous.
Module 20-5: Water Monitoring Techniques – Dissolved Solids.
Module 20-6: Water Monitoring Techniques – Suspended Solids.
Module 20-7: Radiation Monitoring of Biological Samples.

COURSE 21: RADIOACTIVE MATERIALS DISPOSAL AND MANAGEMENT.

Module 21-1: Waste Disposal Procedures. (Same as Module 25-6.)
Module 21-2: Routine Sampling of Radioactive Waste.
Module 21-3: Waste Disposal Regulations.
Module 21-4: Measurement of External Radioactive Contamination. (Same as Module 25-8.)
Module 21-5: Regulations for Transporting Radioactive Materials.
Module 21-6: Packaging and Monitoring of Radioactive Materials for Shipment. (Same as Module 25-7.)
Module 21-7: Leak Tests of Sealed Radioactive Sources.

COURSE 22: ADVANCED RADIONUCLIDE ANALYSIS.

Module 22-1: Survey Methods Used in Radionuclide Analysis (Sample Collection & Analysis).
Module 22-2: Gamma Spectrometry.
Module 22-3: Alpha Spectrometry.
Module 22-4: Beta Spectrometry.
Module 22-5: Radiochemical Methods of Analysis by Liquid Scintillation Counting.
Module 22-6: Neutron Activation Analysis.
Module 22-7: Determination of Specific Nuclides (In the Environment).

COURSE 23: NUCLEAR CHEMICAL PROCESSES.

Module 23-1: Head-End Treatment.
Module 23-2: Ion Exchange.
Module 23-3: Solvent Extraction.
Module 23-4: Precipitation Techniques and Centrifugation.
Module 23-5: Techniques of Chemical Concentration.
Module 23-6: Diffusion and Enrichment Process.
Module 23-7: Nuclear Waste Handling Processes.

COURSE 24: NUCLEAR SYSTEMS AND SAFETY.

Module 24-1: Neutron Physics. (Same as Module 12-1.)
Module 24-2: Cross Sections and Reactions. (Same as Module 12-2.)
Module 24-3: Fission Rate and Reactor Power. (Sames as Module 12-3.)
Module 24-4: Nuclear Criticality.
Module 24-5: Nuclear Material Inventory Management Techniques.
Module 24-6: Nuclear Plant Safeguards.

COURSE 25: RADIOACTIVE MATERIAL HANDLING TECHNIQUES.

Module 25-1: Glove Box Operations – Fundamentals.
Module 25-2: Glove Box Operations – Advanced.
Module 25-3: Master/Slave Manipulator – Fundamentals.
Module 25-4: Master/Slave Manipulator – Advanced.
Module 25-5: Remote Sampling Techniques.
Module 25-6: Waste Disposal Procedures. (Same as Module 21-1.)
Module 25-7: Packaging and Monitoring of Radioactive Materials for Shipment. (Same as Module 21-6.)
Module 25-8: Measurement of External Radiation Contamination. (Same as Module 21-4.)

COURSE 26: NONDESTRUCTIVE EXAMINATION (NDE) TECHNIQUES I.

Module 26-1: Visual Tests.
Module 26-2: Leak Tests.
Module 26-3: Hydrostatic Tests.
Module 26-4: Liquid Penetrant.
Module 26-5: Fundamentals of Radiography.
Module 26-6: Radiograph Inspection.
Module 26-7: Radiographic Specifications and Code Requirements.

COURSE 27: METROLOGY.

Module 27-1: Fundamentals of Metrology.
Module 27-2: Fixed Gages, Dividers, Calipers and Micrometers.
Module 27-3: Gage Blocks, Mechanical Comparators and Electronic Comparators.
Module 27-4: Angle Measurement Instruments, Optical Projectors and Surface Texture Gages.
Module 27-5: Tolerancing.
Module 27-6: Calibration.
Module 27-7: Statistical Techniques in Metrology.
Module 27-8: The Total Measurement System.

COURSE 28: WELDING INSPECTION.

Module 28-1: Welding Fundamentals and Processes.
Module 28-2: Shielded Metal Arc and Oxyacetylene Welding.
Module 28-3: Tungsten Inert Gas (TIG), Metal Inert Gas (MIG) and Submerged Arc Welding.
Module 28-4: Weld Joint Verification.
Module 28-5: Qualifications.
Module 28-6: Process Controls.
Module 28-7: Acceptance Inspection.
Module 28-8: Filler Material Control.
Module 28-9: Weld Repair Control
Module 28-10: Records.

COURSE 29: CIVIL/STRUCTURAL INSPECTION.

Module 29-1: Inspection of Construction Operations.
Module 29-2: Structural Steel Materials, Installation and Inspection.
Module 29-3: Concrete Materials.
Module 29-4: Concrete Preparation, Production, Placement and Finishing.
Module 29-5: Concrete Testing and Inspection.
Module 29-6: Prestressed Concrete Materials, Fabrication and Inspection.

COURSE 30: MECHANICAL INSPECTION.

Module 30-1: Pump Inspection.
Module 30-2: Pump Functional Testing
Module 30-3: Valve Inspection.
Module 30-4: Piping Inspection.
Module 30-5: Surface Cleaning Inspection.
Module 30-6: Protective Coating Inspection.
Module 30-7: Pressure Vessel Inspection.
Module 30-8: Rotating Equipment Inspection.

COURSE 31: QUALITY-ASSURANCE PRACTICES.

Module 31-1: Overall Quality Assurance Program.
Module 31-2: Vendor Qualification.
Module 31-3: Receiving Inspection.
Module 31-4: Identifcation, Storage and Handling of Components, Parts and Materials.
Module 31-5: Nonconforming Material.
Module 31-6: Certification and Qualification of Quality-Control Inspectors.
Module 31-7: Auditing for Quality Assurance.
Module 31-8: Document Handling, Storage and Retrieval for Quality Assurance.

COURSE 32: NONDESTRUCTIVE EXAMINATION (NDE) TECHNIQUES II.

Module 32-1: Fundamentals of Ultrasonic Testing.
Module 32-2: Operation of Ultrasonic Test Equipment.
Module 32-3: Fundamentals of Magnetic Particle Testing.
Module 32-4: Operation of Magnetic Particle Test Equipment.
Module 32-5: Fundamentals of Eddy Current Testing.
Module 32-6: Operation of Eddy Current Test Equipment.

APPENDIX C

SUGGESTEDWORKFORCE NEEDS SURVEY INSTRUMENT FOR NUCLEAR INSTRUMENTATION AND CONTROL TECHNICIANS

Dear Sir:

I am writing to ask for your help. Our school is considering the establishment of a 2-year technical program in the new field of Nuclear Instrumentation and Control. Prior to establishing such a program, I have been asked to conduct a survey of the present and future needs in this locale for technicians with this special training. I have enclosed the survey, which should take just a few minutes to complete. When you are done, simply place this survey in the enclosed stamped addressed envelope and return. If you wish a copy of the results of this survey, please so indicate at the end of the questionnaire.

If, for some reason, this questionnaire does not apply to your specific area of responsibility at your ogranization, please pass it on to someone to whom it may be more appropriate.

I appreciate your efforts in behalf of this new occupational training program in the state.

Sincerely,

_____
Title

TYPICAL WORKFORCE NEEDS SURVEY INSTRUMENT FOR NUCLEAR INSTRUMENTATION AND CONTROL TECHNICIANS

Name of company, institution, or government division:

_____

_____

Definition: Nuclear Instrumentation and Control Technician:

Performs the inspection, analysis, calibration and repairs and routine maintenance of instrumentation and control systems (including computer maintenance).

Yes No

1. _____ _____ If your company employs Nuclear Instrumentation and Control Technicians, were they trained at a technical institute?

2. _____ _____ Do you have current vacancies for nuclear Instrumentation and Control Technicians?

3. Please indicate the typical beginning salary a nuclear Instrumentation and Control Technician might expect to receive in your company.

a. $700-800/mo. _____
b. $801-1000/mo. _____
c. $1001-1200/mo. _____
d. $1201-1400/mo. _____
e. $1401-1600/mo. _____
f. Greater than $1600/mo. _____

4. In your opinion, your need for nuclear Instrumentation and Control Technicians during the next ten years will:

_____ decrease
_____ remain the same
_____ increase by 0-25%
_____ increase by 26-50%
_____ increase by 51-75%
_____ increase by 76-100% or more

5. Can you give an estimate of the total number of nuclear Instrumentation and Control Technicians you will need in the next five year period?

1980 _____
1981 _____
1982 _____
1983 _____
1984 _____

6. As you employ nuclear Instrumentation and Control Technicians in the future, would you:

_____ prefer to train these individuals yourself?
_____ prefer to hire individuals trained in nuclear instrumentation fundamentals in a recognized and approved institution?

7. Please circle those items in which you think the nuclear Instrumentation and Control Technician should receive specific training:

I. Fundamentals of reactor theory.
   A. Fission process.
   B. Energy release.
   C. Neutron multiplication.
   D. Source effects.
   E. Control-rod effects.
   F. Criticality indications.
II. Design features of core.
III. Mechanical design features of the reactor system.
IV. General operating characteristics.
   A. Causes and effects of temperature.
   B. Pressure and reactivity changes.
   C. Effects of load changes.
   D. Operating limitations and reasons for them.
V. Design, components and functions of reactivity control mechanisms and instrumentation.
VI. Design, components and functions of safety systems.
   A. Instrumentation.
   B. Signals.
   C. Interlocks.
   D. Automatic and manual features.

VII. Components, capacity and function of reserve and emergency systems.

VIII. Shielding, isolation and containment procedures for the facility/plant (specific).

IX. Balance of plant – turbines, condensers, pumps, valves, piping, heat exchangers, generators, and auxiliary equipment.

X. Nuclear instrumentation and/or control in the following specific areas:

- A. Neutron monitoring systems.
- B. Reactor protection systems.
- C. Process radiation monitoring systems.
- D. Area and environmental monitoring systems.
- E. Counting room and personnel radiation protection monitoring.
- F. Startup range monitoring.
- G. Power range monitoring.
- H. Traversing in-core probe (TIP).
- I. Noise and installation problems.
- J. Reactor manual control systems.
- K. Control rod and information systems.
- L. Card circuit analysis.
- M. Detection methods.
- N. Pulse circuits.
- O. Pulse shaping methods for spectroscopy.
- P. Resolution in spectroscopy systems.
- Q. Amplifiers.
- R. Timing circuits.
- S. Multichannel pulse height analyzers.
- T. Multiparameter and computer analysis.
- U. Transform methods in transient analysis.

XI. Other – Please list:

_____

_____

_____

_____

_____

8. Due to specific duties, titles for a nuclear Instrumentation and Control Technician may vary; which of the following titles are used by your company to describe these individuals?

_____ Instrumentation and Control Technician.

_____ Control System Technician.

_____ Process Instrumentation Technician.

Other – Please list:

_____ _____

_____ _____

_____ _____

_____ _____

_____ _____

_____ _____

9. Please indicate the type of instrumentation your company operates:

_____

_____

_____

_____

10. Would you classify your company's principal endeavor as:

_____ Electrical power production.

_____ Research and development.

_____ Nuclear materials processing and disposal.

_____ Equipment manufacturer.

_____ University or private training consultant.

_____ Other (specify) _____

11. Comments: Please include any additional information which you feel would help us identify the need in numbers and competencies for nuclear Instrumentation and Control Technicians.

_____

_____

_____

_____

_____

Yes No

12. _____ _____ Would you like to receive a copy of the report summarizing the results of this survey?

Please mail to: _____

_____

_____

_____

Your kind assistance in completing this survey questionnaire is appreciated.

APPENDIX D
UNIVERSITIES WITH RESEARCH REACTORS

Brigham Young University (L-77)
California State Polytechnic College (AGN-201)
Catholic University (AGN-101)
Columbia University (TRIGA)
Cornell University – Zero Power Reactor (ZPR)
Cornell University (TRIGA)
Massachusetts Institute of Technology (CP-5)
Michigan State University (TRIGA)
North Carolina State University (Polstar)
Ohio State University
Oregon State University (TRIGA)
Penn State University (TRIGA core)
Purdue University
Reed College (TRIGA)
Rhode Island (AEC)
State University of New York (PULSTAR)
Stanford University
Texas A & M (TRIGA)
Texas A & M (AGN-201M)
Tuskegee Institute (AGN-201)
University of Arizona (TRIGA)
University of California at Irvine (TRIGA)
University of California at Los Angeles (Argonaut)
University of California at Santa Barbara (L-77)
University of Delaware (AGN-201)
University of Florida (Argonaut)
University of Illinois (TRIGA)
University of Illinois (LPRA)
University of Kansas
Georgia Institute of Technology (CP-5)
Idaho State University (AGN-201)
Iowa State University
Kansas State University (TRIGA)
University of Lowell
Manhattan College
University of Maryland (TRIGA)
University of Michigan
University of Missouri at Rolla
University of Missouri at Columbia
University of New Mexico (AGN-201)
University of Oklahoma (AGN-201)
University of Texas (TRIGA)
University of Utah (AGN-201)
University of Virginia (Pool)
University of Virginia (Cavalier)
University of Washington
West Virginia University
University of Wisconsin (TRIGA core)
Virginia Polytechnic Institute
Washington State University (TRIGA core)
Worcester Polytechnic Institute
Memphis State University (AGN-201)

APPENDIX E

EQUIPMENT LIST WITH COST, QUANTITY AND VENDOR DATA

COURSE	TYPE OF EQUIPMENT	UNIT COST	QUANTITY REQUIRED	TOTAL COST
	RADIATION			
1	Alarm monitor, 1 per entrance to radiation area	$ 475	1	$ 475
12	Analyzer, multi-channel pulse height	8,500	1	8,500
1;12	Chart of nuclides	3	3	9
1	Coat, white knee-length lab, disposable	64/25	50	128
6	Compensated ion chamber	620	1	620
6	Uncompensated ion chamber	620	1	620
	Decontamination kit with radiation signs and labels, ropes, cleaner, brushes	220	1	220
11	Densitometer	4,900	1	4,900
1	Dosimeter, direct reading pocket	80	48	3,840
1	Dosimeter charger	65	5	325
11	Dosimetry film, Type NTA and Type 3	75/box	1 box ea	150
1;11	Dosimeter, thermoluminescent (TLD)			
	Annealed calibration source	600	1	600
	Holder	8	72	576
	Muffle furnace	700	1	700
	Reader	5,700	1	5,700
	TLD chips TLD 100 (LiF)	100/10	240	2,400
	Forceps	1	25	25
11	Electrometer	300	1	300
all	Film badge	10	1 ass't	10
all	Gloves, disposable rubber	15/100 pr	500 pr	75
2	Ionization counter, 2 π, gas-flow	1,500	2	3,000
11	NaI (TI) crystal, with photomultiplier tube and preamplifier	250	12	3,000
		250	12	3,000
6	Neutron detector	1,100	1	1,100
6	Neutron source, obtainable from DOE for cost of shipping		1	
1;2;5;11;12	Radioactive sources in exempt quantities	850	1 ass't	850
2	Ratemeter, ion-chamber	600	12	7,200
1;5;11;12	Scaler-rate meter, G-M type	1,500	12	18,000
	G-M detector, end-window	125	12	1,500
	G-M detector, side-window	75	12	900
1	Shoe covers, disposable	3/pr	48 pr	144
all	Storage container, radioactive waste	275	1	275
11	Survey meter, ion-chamber	660	2	1,320
5;6;12	Survey meter, neutron with BF_3 detector	1,220	2	2,440
1;11	Survey meter, G-M portable	600	12	7,200
all	Workbench modules:			
	decay cabinet	1,300	12	15,600
	sink and waste	1,850	12	22,200
	storage	3,000	12	36,000
	ELECTRICAL			
3	Decade resistance box (5 place)	125	1	125
33;34	d/p cell, electronic, 4-20 mA output	700	4	2,800
33	Instrumentation process control trainer, 3-mode pneumatic	1,800	2	3,600
3	Millivoltmeter, 0-50 mV range	200	12	2,400
1;6	Oscilloscope, cathode-ray	1,500	2	3,000
3	Potentiometer, dial type with built-in standard cell	600	1	600
35	Power supply, 0-30 V d.c. regulated Hewlett-Packard, 6015A or equivalent	200	4	800

Estimated equipment costs based on 1979 prices.

COURSE	TYPE OF MATERIAL	UNIT COST	QUANTITY REQUIRED	TOTAL COST
33;34;35	Strip-chart recorder			
	Electronic	2,500	4	10,000
	Electronic twin-pen	3,000	4	12,000
	Pneumatic	2,000	4	8,000
34	Transducer, current to pneumatic	350	4	1,400
6	Voltage regulator	175	4	700
3	Voltmeter, 3.5 digit, (0-50 mV)	100	12	1,200
34	Variable-frequency sinewave generator, 20 mA output into 600 Ω load, 0-1 mHz	400	2	800
	MECHANICAL			
3	Barometer, mercury	280	1	280
4	Calorimeter	25	1	25
33	Controller, pneumatic, Foxboro 120 or equivalent	350	4	1,400
33	Control valve			
	Pressure activated diaphragm, 1" body, ½" trim, single seat	1,200	6	7,200
	Pressure activated, 3/4" body, Fisher 512 RGS or equivalent	200	6	1,200
33;34	d/p cell, pneumatic, Foxboro 13A or equivalent	500	4	2,000
3	Flowmeter, rotating turbine	325	4	1,300
33	Flow transmitter	700	2	1,400
3;4;35	Gages			
	Hydraulic press and pressure	95	4	380
	Instrument-air			
	High-volume	750	1	750
	Low-volume	750	1	750
	Pressure, Ashcroft 1082-S or equivalent	100	6	600
35	Hydraulic tester Ametek 3-TA or equivalent	1,200	1	1,200
4	Hydrometer			
	All-purpose	14	4	56
	Commercial	12	4	48
34	Loading station, pneumatic, Foxboro 57SRG2 or equivalent	250	4	1,000
33	Level transmitter, pneumatic	500	2	1,000
3;33	Manometer, 30" U-tube	85	4	340
35	Nitrogen tank	95	1	95
33;34	Orifice meter, Perry Equipment Corp.			
	Type 120 or equivalent	200	2	400
	Type 1430 or equivalent	200	2	400
3;4	Orifice plates	8	3	24
34	Oxygen tank	95	1	95
4	Pascal's vase, metallic diaphragm	275	1	275
33;34;35	Pump			
	Centrifugal, 30 gpm	425	1	425
	Jacuzzi, 3 RMS/A or equivalent	385	1	385
	Jacuzzi, 3 RMZB1 or equivalent	450	1	450
3	Rotameter	275	1	275
4;12	Samples of iron, aluminum, low carbon steel, medium carbon steel; high carbon steel, cast ion, alloy steel, chromium steel	10	1 ea	80
35	Tester, dead weight	8,000	1	8,000
3	Venturi tube			
	DIMENSIONAL			
all	Meter stick	3	12	36
1	Yardstick	2	12	24
	HARDWARE			
3;4	Pipe and assorted fittings, galvanized	100	1 ass't	100
3;4	Tubing			
	Glass	68/25#	50#	136
	Rubber	50/12 ft	100 ft	420

Estimated equipment costs based on 1979 prices.

COURSE	TYPE OF MATERIAL	UNIT COST	QUANTITY REQUIRED	TOTAL COST
3;5;33;34	Valves			
	Air vent, butterfly, check diaphragm, gate, globe, motor actuated, plug, pressure actuated, V-pattern, 3-way, 4-way, needle	225/ass't	12 ea	2,700
	TEMPERATURE MEASUREMENT			
3	Resistance temperature detector			
	Open wire element, 100	725	1	725
	Standard platinum, 100	725	1	725
3	Temperature recorder	720	1	720
3,4	Thermometer			
	General laboratory	40/5	ass't	200
	NBS-, 2° standard, -10°-100°C	740	1	740
	NBS, test thermometer	26	12	312
3	Wire			
	Copper lead	2.50/ft	250 ft	625
	Thermocouple, iron-constantan	160/50 ft	50 ft	160
	AUXILIARY			
1	Absorber set, aluminum and lead	180/set	6 set	1,080
4	Balance, triple beam	95	2	190
3	Beakers, with spout, 50-1000 ml sizes	110/12 sets	12 sets	110
3	Centrifuge	395	1	395
3	Desiccator	70	6	420
4	Discs or rods: LiF	350	1 ass't	350
11	Filters, low Z	10	36	360
3	Flasks,			
	Dewar with holder	180/6	6	180
	Erlenmyer 50-500 ml sizes	80/set	12 sets	960
1;3	Sample holders	85	12	1,020
3;4	Hot plate with motorized stirrer	140	3	420
4	Jar, hydrometer	12	ass't of 30	360
4	Lamp, heat	20	12	240
33;34;35	Tank, reservoir			
	20 gal, 24" diam x 10" height	100	4	400
	20 gal, 10" diam x 60" height	150	4	600
	50 gal	175	4	700
3	Telescope, 10x with mount	100	1	100
1	Timer	135	12	1,620
3	Tubes, test, assorted sizes	45/24 sets	48 sets	90

Estimated equipment costs based on 1979 prices.

APPENDIX F

SUGGESTED LIBRARY REFERENCES AND MATERIALS

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ATOMIC DATA AND NUCLEAR DATA TABLES
Academic Press, Inc.
111 Fifth Avenue
New York, NY 10003

ATOMIC ENERGY CLEARINGHOUSE
Congressional Information Bureau, Inc.
Colorado Bldg. 14th & G Streets N.W.
Washington, DC 20005

ENERGY
Business Communications Co.
471 Glenbrook Rd.
Stamford, CT 06906

ENERGY DEVELOPMENTS
International Review Service
15 Washington Place
New York, NY 10003

ENERGY REPORTER
Federal Energy Administration
Old Post Office Bldg., Room 307b
Washington, DC 20461

HANFORD NEWS
Department of Energy
Atlantic Richfield Hanford Co.
P. O. Box 250
Richland, WA 99352

HEALTH PHYSICS JOURNAL
(See Associations and Societies)
4211 39th Street, N.W.
Washington, DC 20016

INIS ATOMINDEX
UNIPUB
P. O. Box 433
Murray Hill Station
New York, NY 10016

INSTITUTION OF NUCLEAR ENGINEERS JOURNAL
(Formerly NUCLEAR ENERGY)
Institute of Nuclear Engineers
1 Penerley Rd.
London SE6 2LQ, England

NUCLEAR INDUSTRY STATUS
Nuclear Assurance Corp.
24 Executive Park West
Atlanta, GA 30329

NUCLEAR INFO
Atomic Industrial Forum
475 Park Avenue South
New York, NY 10016

NUCLEAR INSTRUMENTS AND METHODS
North Holland Publishing Co.
Box 211
Amsterdam, Netherlands

NUCLEAR MATERIALS MANAGEMENT
Institute of Nuclear Materials Management
Seaton Hall
18 Seaton Hall
Manhattan, KS 66506

NUCLEAR NEWS
American Nuclear Society
244-a, E. Ogden Avenue
Hinsdale, IL 60521

NUCLEAR POWERPLANT PERFORMANCE
Nuclear Assurance Corp.
24 Executive Park West
Atlanta, GA 30329

NUCLEAR SAFETY
U.S. Nuclear Regulatory Commission Publication
Superintendent of Documents
Government Printing Office
Washington, DC 20402

NUCLEAR STANDARDS NEWS
American Nuclear Society
244 E. Ogden Avenue
Hinsdale, IL 60521

JOURNAL OF NUCLEAR MATERIALS
North Holland Publishing Co.
Box 211
Amsterdam, Netherlands

JOURNAL OF NUCLEAR SCIENCE AND TECHNOLOGY
Atomic Energy Society of Japan
c/o Japan Atomic Energy Research Institute
1-13 Shimbashi, Minato-Ku
Tokyo, Japan

JOURNAL OF PHYSICS: NUCLEAR PHYSICS
Institute of Physics
47 Belgrave Square
London SWIX 8QX, England

NUCLEAR FUEL STATUS AND FORECAST
Nuclear Assurance Corp.
24 Executive Park West
Atlanta, GA 30329

NUCLEAR TECHNOLOGY
American Nuclear Society, Inc.
244 E. Ogden Avenue
Hinsdale, IL 60521

NUCLEONICS WEEK
McGraw-Hill, Inc.
1221 Avenue of Americas
New York, NY 10020

OAK RIDGE ASSOCIATED UNIVERSITIES NEWSLETTER
Oak Ridge Associated Universities, Inc.
Information Services Dept.
Box 117
Oak Ridge, TN 37830

OAK RIDGE NATIONAL LABORATORY REVIEW
Oak Ridge National Laboratory
P. O. Box X
Oak Ridge, TN 37830

REVIEW OF SCIENTIFIC INSTRUMENTS
American Institute of Physics
335 East 45th Street
New York, NY 10017

JOURNALS (GENERAL INSTRUMENTATION)

CONTROL ENGINEERING
Dun-Donnelly Publishing Company
222 South Riverside Plaza
Chicago, IL 60606

ELECTRONIC INSTRUMENTATION
Milton S. Kiver Publishing Company
222 West Adams Street
Chicago, IL 60606

INSTRUMENT AND APPARATUS NEWS
Chilton Company
Chestnut and 56th Streets
Philadelphia, PA 19139

INSTRUMENTS AND CONTROL SYSTEMS
Chilton Company
Chilton Way
Radnor, PA 19089

INSTRUMENTATION
Honeywell Industrial Division
1100 Virginia Drive
Fort Washington, PA 19034

INSTRUMENTATION AND MEASUREMENT
Institute of Electrical & Electronic Engineers
United Engineering Center
345 E. 47th Street
New York, NY 10017

INSTRUMENTATION TECHNOLOGY
Instrument Society of America
400 Stanwix Street
Pittsburgh, PA 15222

JOURNAL OF DYNAMIC SYSTEMS MEASUREMENT & CONTROL
American Society of Mechanical Engineers
345 E. 47th Street
New York, NY 10017

AGENCIES, ASSOCIATIONS, AND SOCIETIES

Additional relevant reference materials may be obtained directly from the following sources.

AGENCIES

International Atomic Energy Agency (IAEA)

IAEA Proceedings and Directory available for purchase from its Division of Publications.

International Commission on Radiation Units and Measurements (ICRU)

International Commission of Radiological Protections (ICRP)

National Council on Radiation Protection and Measurements (NCRP)

United Nations Scientific Committee on the Effects of Atomic Radiation

United States Government

Department of Energy

Nuclear Regulatory Commission

All NRC/DOE documents are available for purchase from the National Technical Information Service of the U.S. Department of Commerce, 5285 Port Royal Road, Springfield, VA 22151

ASSOCIATIONS AND SOCIETES

American Concrete Institute (ACI)

American Institute of Physics (AIP)

American National Standards Institute (ANSI Standards)

American Nuclear Society (ANS)

American Society of Mechanical Engineers (ASME)

ASME Boiler and Pressure Vessel Code

American Society of Quality Control (ASQC)

American Society for Testing Materials (ASTM)

American Welding Society (AWS)

Atomic Industrial Forum (AIF)

Health Physics Society

Institute of Electrical and Electronic Engineers (IEEE)

Instrument Society of America

AUDIO-VISUAL AIDS

In addition to aids used by the instructor(s), there are available films and other pertinent materials showing research or production that should be available to students of nuclear technology on a selective basis. Frequently these items can be made available by equipment vendors, utility companies, Government agencies and other organizations that may be represented on a program's industrial advisory committee.

American Nuclear Society
555 North Kensington Avenue
La Grange Park, IL 60525

American Soecity of Mechanical Engineers
Education Division
345 East 47th Street
New York, NY 10017

Babcock and Wilcox
Manager, Special Products and Service Marketing
Nuclear Power Generation Division
Lynchburg, VA 24505

DOE - Technical Information Center
Oak Ridge National Laboratory
P. O. Box 62
Oak Ridge, TN 37830

General Electric Company
Manager - BWR Training
Mail Code 594
175 Curtner Avenue
San Jose, CA 95125

Health Physics Society
4211 39th St., NW
Washington, D.C. 20016

Instrument Society of America
400 Stanwix Street
Pittsburgh, PA 15222
- a. What is Instrumentation (Slide Presentation)
- b. Automatic Process Control (16 mm Sound Film).
- c. Principles of Frequency Response (16 mm Sound Film).

McGraw-Hill Book Company
330 West 42nd Street
New York, NY 10036
Catalog of Films, Film Loops, Records, and Transparencies.

The Pennsylvania State University
Audio-Visual Services
7 Willard Building
University Park, PA 16802
- a. Films for Business and Industrial Skills
- b. Films for Engineering Education
- c. Films for Mathematics and Physical Sciences

U.S. Department of Health, Education and Welfare
Public Health Service
Bureau of Radiologic Health
Rockville, MD 20852

APPENDIX G

SAMPLE COSTING CALCULATIONS

SAMPLE CALCULATION NO. 1

(Two faculty members and full enrollment of students)

Assumptions:
- 24 1st-yr students.
- 16 2nd-yr students.
- 14 grads annually after 2nd yr.
- 1 Dept. head @ $24,000 - 1st yr salary.
- 1 Instructor (beginning 2nd yr) @ $18,000 - 1st yr salary.
- 1/2 Secretary @ $8,000 - 1st yr salary.
- Benefits and overhead equal to 50% of annual salaries.
- Facility modifications cost of $31,250.
- Initial capital equipment cost of $88,500 (for 1st-yr courses only).
- Additional capital equipment cost of $113,500 for 2nd-yr courses.
- Annual expendables cost of $13,000 for both 1st- and 2nd-yr courses.
- Miscellaneous annual costs of $5,000 (library, travel, seminars, etc.).

Calculation:

Initial expenditures	Facility	$ 31,250.00		
	Equipment	88,500.00		
			$ 119,750.00	
1st-yr expenditures	Dept. head	$ 24,000.00		
	Secretary	4,000.00		
	Benefits & Overhead	14,000.00		
	Expendables	6,500.00		
	Misc.	2,500.00	51,000.00	
			$ 170,750.00	$ 170,750.00
2nd-yr equipment expenditures			$ 113,500.00	
2nd-yr expenditures	Dept. head	$ 24,000.00		
	Secretary	4,000.00		
	Instructor	18,000.00		
	Benefits & Overhead	23,000.00		
	Expendables	13,000.00		
	Misc.	5,000.00	87,000.00	
			$ 200,500.00	$ 200,500.00
				$ 371,250.00

If equipment and facilities costs are developed over a five-year period, the following approximations apply:

Exp. Item	1st Yr	2nd Yr	3rd Yr	4th Yr	5th Yr
Personnel*	$ 28,000	$ 47,400	$ 49,770	$ 52,260	$ 54,870
Benefits & Overhead	14,000	23,700	24,885	26,130	27,435
Equipment	10,000	25,750	25,750	25,750	25,750
Facilities	6,250	6,250	6,250	6,250	6,250
Expendables	6,500	6,500	6,500	6,500	6,500
Miscellaneous	2,500	5,000	5,000	5,000	5,000
Annual Totals	$ 67,250	$114,600	$118,155	$121,890	$125,805

*5% annual salary increase included.

SAMPLE CALCULATION NO. 2

(One faculty member and minimum enrollment.)

Assumptions:
12 1st-yr students.
8 2nd-yr students.
6 grads annually after 2nd yr.
1 Dept. head/instructor @ $20,000 - 1st-yr salary.
1/2 Secretary @ $7,000 - 1st-yr salary.
Benefits and Overhead equal to 40% of annual salaries.
Facility modification cost of $6,000.
Initial capital equipment cost of $45,000 (for 1st-yr courses only).
Additional capital equipment cost of $65,000 for 2nd-yr courses.
Annual expendables cost of $6,500 for both 1st- and 2nd-yr courses.
Miscellaneous annual costs of $5,000 (library, travel, seminars, etc.).

Calculation:

Initial expenditures	Facility	$ 6,000.00		
	Equipment	45,000.00		
			$ 51,000.00	
1st-yr expenditures	Dept. head	$ 20,000.00		
	Secretary	3,500.00		
	Benefits and Overhead	9,400.00		
	Expendables	3,000.00		
	Misc.	5,000.00		
			40,900.00	
			$ 91,900.00	$ 91,900.00
2nd-yr equipment expenditures			$ 65,000.00	
2nd-yr expenditures	Dept. head	$ 21,000.00		
	Secretary	3,700.00		
	Benefits and Overhead	12,350.00		
	Expendables	6,500.00		
	Misc.	5,000.00		
			48,550.00	
			$ 113,550.00	$113,550.00
				$205,450.00

If equipment and facilities costs are developed over a five-year period, the following approximations apply:

Exp. Item	1st Yr	2nd Yr	3rd Yr	4th Yr	5th Yr
Personnel*	$ 23,500	$ 24,700	$ 25,935	$ 27,237	$ 28,593
Benefits and Overhead	9,400	9,880	10,374	10,892	11,437
Equipment	11,000	25,000	25,000	25,000	25,000
Facilities	1,200	1,200	1,200	1,200	1,200
Expendables	3,200	6,500	6,500	6,500	6,500
Miscellaneous	2,000	5,000	5,000	5,000	5,000
Annual Totals	$ 50,300	$ 72,280	$ 74,009	$ 75,823	$ 77,730

*5% annual salary increase included.

SAMPLE CALCULATION NO. 3

(Industrial Training Facility)

Assumptions: Facility diversion: $60,000
Equipment diversion: $55,000
On-staff instructor(s) - annual salary $28,000.
1/2 Secretary - annual salary $9,000.
Benefits and Overhead - 50% of annual salaries.
Annual expendables cost of $1,200/student.
Miscellaneous cost of $300/student.
10 students/yr.

Calculation:

1st-yr expenditures	Facility	$ 60,000.00	
	Equipment	55,000.00	
	Instructor	28,000.00	
	Secretary	4,500.00	
	Benefits and Overhead	16,250.00	
	Expendables	12,000.00	
	Misc.	3,000.00	
			$178,750.00

NOTE: This calculation suggests costs for academic preparation only; it does not include observation, simulator training or coaching for NRC license examination.

ESTIMATED LIBRARY MATERIAL COST.

Library materials for this technology, predicated on 1979 costs, may be estimated from the following:

Initial Costs	Minimum
References	$ 1,500.00
Journals	200.00
Periodicals	100.00
Miscellaneous (subscriptions, etc.).	50.00
	$ 1,850.00

Annual Costs	
References	$ 175.00
Journals	175.00
Periodicals	100.00
Miscellaneous (subscriptions, etc.).	50.00
	$ 500.00